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Short-Term Memory for Nonsense Strings in Children With Reading Disabilities

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Short-term Memory for Nonsense Strings in Children with Reading Disabilities

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ABSTRACT

A large body of evidence exists that demonstrates strong correlations between reading ability, phonological awareness and memory. The current study was designed to compare the performance of 24 10-year-old students with reading disabilities and a group of 24 8-year-old average readers, who were matched according to reading age. These students were given a decoding task requiring the recall of nonsense strings. This task was designed to measure working memory for phonological elements. An ANOVA yielded a significant main effect for group in favour of the older students, and a main effect for total errors and vowel and space location. Participants found CVC strings easier to recall than either CCV or VCC strings. They also found - - - XX (where X represents a space) nonsense strings to be easier to recall than either X - - - X or XX - - - space locations. Phonological ability was then partialed out in an ANCOVA, and the main effect for group was retained. The different strategies used by each group were examined statistically and it was found that the students with reading disabilities employed problem-solving strategies to help them to complete the task.

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signature ....[redacted]..[redacted]

Date 10.2.99

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CHAPTER 1

INTRODUCTION

This study was designed to examine the ability of children to remember letter sequences. It was of particular interest to determine whether or not children with reading disabilities perform differently from children of average reading ability when recalling unfamiliar letter strings.

1.1. Background to the Study

Reading is a skill that is necessary for gaining an education, working, and for some leisure activities. Those people who fail to attain a functional reading standard experience great difficulty completing simple tasks such as using a telephone book, reading labels on packaged food, filling in forms, applying for a job, obtaining a driver's licence, or reading hire purchase agreements and insurance policies. Adults with reading problems can experience difficulties in relation to their employment opportunities and overall quality of life. Children with reading problems are likely to experience difficulties in most aspects of their education. Reading is required for most school subjects. Even specialized skill subjects such as mathematics and science require the reading of background information and questions to successfully complete set tasks. Teachers of children with reading difficulties expend enormous amounts of energy and time in the planning and preparation of learning opportunities that will assist their students to overcome reading deficits. Gillet & Temple (1990) suggested that "helping students become effective, enthusiastic readers is one of the greatest challenges facing teachers today" (p. iii). It is not surprising that understanding how children learn to read has been the subject of thousands of research investigations (Carroll, 1985; Gillet & Temple, 1990).

Recent reading research has provided helpful analysis of the reading process giving teachers a clear starting point to the diagnoses of specific weaknesses. Carroll (1985, p.31) summarized the findings of this research with eight fundamental skills necessary for proficient reading.

1. Knowledge of the language to be read.
2. Ability to dissect spoken words into component sounds, or phonemes (Liberman, Shankweiler & Liberman, 1992).
3. Knowledge of the letters of the alphabet.
4. Understanding of the left-to-right reading direction.
5. Knowledge of the correspondence between written letter patterns, or graphemes, and sounds (Davies & Ritchie, 1998).
6. Ability to recognize printed words.
7. Ability to extract meaning from individual printed words to understand the complete written message.
8. Ability to reason and think about what is read.

While each of the eight skills is important to the reading process, it is points 2 and 5 that are of particular relevance to this study. The ability to dissect spoken words into component sounds (point 2) is a skill that is crucial to successful reading (Stahl & Murray, 1994). This skill has been named *phonological awareness* (Ehri, 1989) and is described as the capability to consciously analyze and manipulate the sound structure of spoken words by dividing words into their constituent sounds or by deleting or substituting sounds. Phonological awareness is the capacity to hear the word "*fish*" and discern that it is comprised of three separate and individual sounds, */f/ /i/* and */sh/*. The initial sound being */f/*, the medial sound being */i/* and the final sound being */sh/*. The development of phonological awareness to the level of discerning the component sounds in words is an important prerequisite for beginning to read. This skill is so important to skilled reading that tests of phonological awareness are the best single predictor of reading success (McBride-Chang, 1995; McDougall, Hulme, Ellis & Monk, 1994; and Walton, 1995).

Learning the relationship between sounds in words and their corresponding written forms or graphemes (point 5) can be a daunting task for beginning readers. Children must learn to form connections between the letters they see in words and the various spellings of each of the sounds of spoken language (Ehri and Robbins cited in Walton, 1995, p. 588). The magnitude of this challenge becomes apparent when one reflects that whilst there are 26 letters in the alphabet, there are actually 44 sounds in the English language (Davies & Ritchie, 1998). The task becomes even larger when it is realized that each of those 44 sounds can be spelled in several different ways e.g. the /ch/ sound is spelt "ch" in chin and "tch" in watch. Gough and Tunmer (1986) have named the complicated process of deciding which phoneme is being represented by a particular grapheme, as *decoding ability*. They suggest that children who fail to learn to decode will experience reading problems.

Some children have low phonological awareness and also experience difficulty learning the letter-sound correspondence rules of written language (Siegel & Ryan, 1988). Children who experience problems recalling letter-sound correspondence rules must sound out each new word they encounter in a text because they do not immediately recall the relationship between the sounds they know in spoken words and the letters used to represent them in written words. These children read slowly because they need to mentally apply a sound to the strings of letters in new words and then link the sounds together to pronounce the word. Students with poor knowledge of the phoneme-grapheme correspondence rules find this task extremely difficult and often apply trial and error strategies to decode pieces of text. They may guess that the word "ball" is "boy" or "bat" if they remember the letter /b/. If the letter /b/ is not familiar to them however, they may substitute any known word for the unknown word. A large amount of energy and attention is expended decoding in this manner leaving little reserve, in either memory or time, for remembering and comprehending what has been read. Poor decoding skill may affect reading speed and reading comprehension and can retard reading ability to the point that reading age is not consistent with the chronological age and intelligence of the student.

Unlike students with reading disabilities, successful readers develop phonological skills to the point that they are able to identify, reflect on, manipulate and decode the written equivalents of phonological units (Tunmer, 1992). These children grasp letter-sound correspondence rules quite quickly and are able to focus their attention on higher level reading skills, such as reasoning and thinking (one of Carroll's eight reading skills mentioned previously). Skilled readers develop strategies that enable them to gain valuable information from their reading experiences. This information can be integrated with long-term memories to form new memories (Borkowski, 1992). These strategies include the application of *metacognitive skills*. Metacognition is defined as knowing about knowing (Nelson and Nairn, cited in Metcalfe, 1996). Metacognition involves being aware of strategies that will assist in solving a problem and being able to use self-regulatory procedures to complete tasks successfully (Chan & Cole, 1986). In reading, this involves knowing how and when to use strategies that may be needed to solve problems associated with reading a text. For example a child may apply phonics rules to work out unfamiliar words; or apply the 'what', 'when', 'who' 'where' 'why' focus questions to determine the main idea of a text.

Recent research has established that significant links exist between reading ability, phonological skill and memory (Hansen & Bowey, 1994; McDougall et al., 1994; Siegel & Ryan, 1988; Swanson, 1992). Research relating to memory that has been conducted since the 1960's has provided a rich source of information on the nature of the memory processes that are activated during reading. Atkinson and Shiffrin's (1968), *information-processing model of memory*, which consisted of three interactive parts, has long been considered to be a useful and important tool in making sense of the phenomena of memory (Pashler & Carrier, 1996).

The first component of this model is the *sensory memory*. The sensory memory produces temporary representations within the brain of incoming information from the senses. These representations of visual, auditory, olfactory and tactile information have been described as 'fading versions of the original stimulus" (Pasher & Carrier, 1996). They may last only fractions of seconds and must be acted upon by other memory systems to prevent decay. The visual sensory store, or iconic memory (Guthrie, 1973; Neisser in Massaro & Loftus, 1996), is retained for several hundred milliseconds while the auditory sensory storage (echoic memory) is retained for one or two seconds before decay commences. Sensory memories are either lost through decay or retained through being registered in the short-term memory (Massaro & Loftus, 1996). In reading, the sensory memory makes the initial representation of the letters on the page within the brain.

Nairne (1996 p.101) described the second component of the information-processing model of memory, the short-term memory, as the "active contents of the mind". The short-term memory includes the sensory register of information retained from perceptual analysis (e.g. visual images, spatial information, verbal information and abstract propositions) plus *working memory* which is the vehicle within short-term memory that rehearses, coordinates and processes information (Baddeley and Hitch, 1993). The short-term memory is vital to the reading process as it facilitates phonological awareness, phoneme-grapheme knowledge application and the access and integration of information held in the long-term memory.

The third component of the information-processing model is the *long-term memory*. Long-term memory holds all the permanent memories that are acquired in day to day human functioning. Anderson (1995) described long-term memory as a set of permanent memories that can be activated either when their associated cues are in the environment or through other active memory processes. In reading, the long-term memory stores in the lexicon (or word bank), permanent memories necessary for comprehension and the grammatical, phonemic and graphemic information.

There is an enormous amount of information to be remembered and analyzed during reading and it can reasonably be deduced that an inefficient memory will have a negative effect on reading ability. Siegel and Ryan (1988) found that problems associated with memory capacity affect reading performance. Children may have difficulty remembering letter-sound correspondence rules, word meanings and words that they have read previously in the text.

1.2. Aim of the Study

This study investigates how well students with reading disabilities remember unfamiliar letter sequences compared to students of average reading ability. A task was designed that required students to remember and correctly order nonsense letter strings. To complete the task children used their knowledge of phoneme-grapheme correspondence rules to encode the letter strings, and their working memory to store and rehearse the information prior to recall. Performance on this task depended on children's phonological awareness because it involved the encoding of visual representations (nonsense strings) into a phonological form that could be retained in working memory. Differing levels of phonological awareness between participants may have affected their performance on the measurement task. Therefore phonological awareness was tested using a separate phoneme deletion task and performance on this test was used as a covariate in the study.

The aim was to determine how well students with reading disabilities performed on the task relative to younger students of average reading ability who were at the same reading level. A secondary aim was to investigate the strategies used by members of each group to remember the nonsense strings. The task was administered to a group of students with reading disabilities who were matched by reading age to a group of younger students of average reading ability. It was anticipated that the students with reading disabilities would perform differently to the younger readers of average ability on the working memory task and also use different strategies. The age of the students with reading disabilities contributed to this assumption. The group of students with disabilities consisted of middle and upper primary students while the students of average reading ability consisted of children from grade two and three. The older group was likely to have learned more phonics and problem-solving skills, and metacognitive strategies than the younger students.

1.3. Significance of the Study

This study is designed to investigate how students with reading disabilities process phonological information in working memory, in comparison to students of average reading ability. It is anticipated that aspects of working memory associated with phonological processing may not be accessed efficiently by students with reading disabilities and that students of average reading ability may use working memory more successfully. The study may also show that children, who perform significantly better than others on tasks involving memory for phonological information, are using some form of metacognitive strategy. Research has shown that even students with learning disabilities can enhance their academic performance through the use of metacognitive strategies (Chan & Cole, 1986).

Information that comes to light as a result of this study may prove helpful to classroom teachers who are interested in the problems faced by students with reading disabilities. Teachers who wish to assist students to overcome reading problems must diagnose the specific nature of the problem before choosing a teaching strategy that will be appropriate to the child's preferred learning style. It may seem logical to some teachers that students who are reading at the same level regardless of chronological age, are using similar strategies to decode a text. Based on this supposition they may use strategies which prove unsuccessful, to assist older students with reading disabilities. Should the current study show that students with reading disabilities are using different strategies to younger students of the same reading age, teachers can adjust their teaching strategies to meet specific needs.

1.4. Definition of Terms

Phonological Awareness

Phonological awareness is the ability to dissect spoken words into component sounds (Stahl & Murray, 1994). It is described by McBride-Chang (1995) as a "conscious knowledge about the phonemes in language" p. 180. It involves the implicit understanding that the words used in spoken language consist of various sounds that can be manipulated e.g. the sound after /c/ in 'cat' is /a/, and the final sound in the word is /t/.

Phonemic Awareness

Phonemic awareness is vital to developing an understanding of the alphabetic principle and how "print maps on to speech" (Spector, 1995. p.38). It is the knowledge of how the spoken words can be broken down into individual sounds which can be represented by letters in written words (Spector, 1995).

Phoneme-grapheme Correspondence

Phoneme-grapheme correspondence is knowledge of the specific correspondence between groups of letters and the sounds they represent and "between a string of graphemes and word representation" (Perfetti, 1986, p 12.). It involves knowing that the phoneme /c/ in 'cat' is spelt with the grapheme 'c', while the phoneme /c/ in 'sock' is spelt with the grapheme 'ck'.

Reading Disability

A learning disability is associated with a significantly lower academic performance than would be expected, based on intelligence level (Fletcher et al., 1994). For the purpose of this study, a child with a reading disability is described as a child of average intelligence whose reading age is two years or more below his or her chronological age.

Working Memory

Working memory is the mechanism that selects short-term memories and actively maintains them while completing various cognitive processes (Nairne, 1996). The working memory consists of the central executive, the visuo-spatial sketchpad and the phonological loop (Baddeley & Hitch, 1993). Each component of working memory is discussed in the literature review.

Metacognitive Strategies

Metacognition is knowledge and control over one's thinking and learning activities (Swanson, 1990). Metacognition involves being aware of strategies and skills that can assist in the performance of a task, and requires self-monitoring and regulation of those processes until the task is accomplished (Brown, 1985)

1.5. Overview of the Thesis

Chapter 2 contains a review of the current literature in the areas of memory and phonological awareness. Theoretical models of memory and reading are examined. Chapter 3 describes the design of the study and the methodology, including the tests used and the testing procedures. Chapter 4 contains the results of the study. Chapter 5 provides a discussion of the findings of the study, the educational implications and suggestions for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter presents a review of the major research findings concerning phonological awareness, working memory and reading disability. It summarizes current research and critically evaluates its relevance and application to the present study. The first part of the discussion examines the relationship between phonological awareness, phonemic awareness, memory and reading ability. A model for working memory is then outlined including links to the current research. The development of reading skill is discussed and the use metacognitive strategies in reading and memory tasks. The challenges faced by those with reading disabilities are discussed with including problems associated with working memory. Finally, the review examines aspects of word reading that are relevant to the current study.

2.1. Development of Phonological Awareness

As children learn to communicate through speech, they assign meanings to the words they hear in spoken language. Gradually, children learn to perceive the individual sounds within words (Stahl & Murray, 1994) and they recognize that words can be broken up into their constituent sounds. Phonological awareness is an understanding that spoken words are made up of separate sounds which can be used in different combinations to form other words (Yopp, 1992). Phonological awareness is a sound-based process that begins to develop in early childhood. It is a vital prerequisite to learning to read and constitutes a cornerstone of skilled reading.

Young children's ability to identify the sounds of speech develops on a continuum. They initially hear the words and phrases spoken by parents as one speech sound (Stahl & Murray, 1994). Over time, and with repeated practice at sounding and learning to say words for themselves, children develop the understanding that there are consecutive phonemes in words. The word "cat", for example, contains three phonemes /c/, /a/ and /t/. Identifying the phonological units in words is quite difficult however, because individual sounds within words are not actually discreet acoustic units. Spectrographic studies have shown that recordings of spoken words cannot be spliced precisely into individual sounds. This is because the sounds within the words actually overlap (Spector, 1995). Spector stated that the sounds in "cat" overlap and cannot be separated into /k/ /a/ and /t/. The /k/ sound is produced first and the /a/ sound is then introduced, but heard simultaneously to the listener's perception of the /k/ sound. The /t/ sound is produced as the /a/ sound is perceived. Young children are able to pronounce words more accurately, and identify the sounds in words as their phonological awareness improves.

Phonological awareness requires the concurrent application of several skills. McBride-Chang (1995) conducted a study with 136 third and fourth grade children relating to the skills involved in phonological awareness. She tested the extent to which IQ, verbal short-term memory and speech perception predicted phonological awareness, and found that all three variables contributed "unique variation to the phonological awareness construct" (McBride-Chang, 1995, p. 185). She suggested that children with phonological awareness are able to perceive a speech segment, and then hold information relating to the speech segment in short-term memory long enough to apply a cognitive process involving the manipulation of the phonemes.

The most useful tests of phonological awareness involve listening to words or nonsense words; deleting, segmenting or substituting phonemes within the word or nonsense word; and then saying the modified word or nonsense word (McBride-Chang & Chang, 1996). Young children may also be asked to identify the initial, medial and final sounds in words. Through such tests the level of phonological awareness of a child can be identified.

Most children acquire spoken language rapidly, automatically and effortlessly in an informal, familiar environment (Mason, 1992). They enter preschool with a substantial vocabulary, adequate syntax and the ability to pronounce most of the phonemes in the English language (Yopp, 1992). The informal structure of spoken language is, however, quite different to the formal language of books, and written language cannot be understood without reading skill. Due to the vast difference between spoken and written language, rapid acquisition of speech skills does not guarantee rapid acquisition of reading skill. Reading instruction builds on the phonological awareness skills that a young child brings to the class and progresses through several levels.

The first stage of phonological awareness is an awareness that words are made up of syllables. Developing readers learn to discern syllabic units within spoken language, e.g. they hear that the word "mummy" and recognize that it consists of two parts, /mum/ and /my/.

The second phonological skill is more difficult to achieve and relates to an awareness of units that are smaller than the syllable (Spector, 1995). Syllables contain two major subunits, the onset and the rime (Treiman, 1992). The onset, may contain a single phoneme or phoneme cluster. The rime usually contains a vowel and final consonant or consonant cluster, with the typical onset-time configuration being CVCC. The onset/rime division in the word "hand" is /h/ and /and/. These sub-syllabic units are more difficult to identify than syllable units. Awareness of onset and rime must be developed before readers can become proficient at more complex tasks.

The most complex phonological decoding skill is at the level of the phoneme or individual sounds. Phonemic awareness involves being familiar with the individual sounds in words and their sequences, and understanding how that information is translated into the spelling patterns of written words (Siegel & Ryan; 1988, Stahl, 1992). Spector (1995) states that two of the most important skills in phonemic awareness are phoneme segmentation and phoneme blending. Segmentation involves identifying the sequence of sounds within words e.g. /c/, /a/ and /t/ are the sounds in "cat", and blending involves putting a number of separate sounds together to make a word e.g. /c/ and /a/ and /t/ joined together make "cat". Another skill in phonemic awareness is recognizing that individual phonemes are shared by words (e.g. the /s/ in "sun" is also found is "bus"). Children also need to learn the standard spelling patterns for each phoneme (e.g. the /c/ sound is spelled "ch" in school, "k" in kitten, "c" in cat, and "ck" in duck).

In the classroom, phonological awareness is identified and taught through activities such as: rhyming, counting the sounds in spoken words, and by phoneme deletion, segmentation or substitution tasks (Stahl, 1992; Tunmer & Hoover, 1992). These activities are designed to prepare young children to begin to read by providing opportunities for them to hear and identify the individual phonemes in words. Children must be aware of how the sound structure of spoken words is transferred to letters on the page before they are able to understand information presented in a printed format.

This requires knowledge of the shapes, orientation and names of individual letters (the alphabet) and knowledge of the various sounds represented by letters and letter blends. It also involves understanding and using the complicated rules and conventions of written language such as capital and lower case letters, grammar, punctuation and sentence structure.

Not all children are able to gain a functional level of phonological awareness skill, and researchers have found that failure or success in achieving this skill can be linked to the acquisition of reading ability (McBride-Chang & Chang, 1996; Stahl & Murray, 1994). Even slight phonological deficits are associated with poor reading ability (Hanson, 1992). Many studies have been conducted to determine the relationship between phonological awareness and reading.

Liberman et al. (1992) reviewed studies in the English, Swedish, Spanish French and Italian languages, and all presented strong evidence that the lack of phonological awareness is related to failure in reading. The work of Lundberg, Olofsson and Wall (cited in Liberman et al., 1992. p. 12) was particularly noteworthy. They administered a battery of linguistic and nonlinguistic tests to 200 kindergarten children. The linguistic tests, which required the child to focus on phonological structure rather than word meanings, included word synthesis tasks, word analysis tasks and phoneme analysis tasks such as rhyming, phoneme segmentation and phoneme reversal. Nonlinguistic tests measured general cognitive function. The finding of this study was that the tasks involving phonological awareness were the most powerful predictors of later reading and writing skills.

Siegel and Ryan (1988) conducted a study that investigated the development of grammatical sensitivity, short-term memory and phonological skills, and the effect of these variables on reading skill. They were particularly interested in the development of phonics skills (such as reading and spelling nonwords), the recognition of the orthographic forms of nonwords and the reading of orthographically irregular words. The participants of the study included students aged 7 to 14 with a variety of different learning profiles (138 were average achievers, 66 were reading-disabled, 65 were arithmetic-disabled and 15 had Attention Deficit Disorder). Siegel and Ryan administered tests of grammatical skills, phonological awareness, phonemic awareness and reading ability and short-term memory. An analysis of variance was conducted on the data collected and it was reported that "word recognition and phonemic awareness were highly related" (Siegel & Ryan, 1988, p. 28.).

Spector (1995) reviewed several research articles on word reading and reading ability, and found strong links between reading ability and decoding ability. She concluded that the difference between poor readers and good readers is most apparent when the text includes large numbers of unfamiliar words or when the task involves reading nonsense words. Phonological awareness, phonemic awareness and word reading skill have all been shown to be strong indicators of reading ability. These skills are facilitated through the working memory.

2.1.1. Phonological Awareness and Memory

Several researchers have found evidence of links between phonological awareness, reading ability and memory for verbal information. Perfetti (1986) suggested that poor readers, with below average decoding skills exhibit deficits in maintaining and manipulating phonological information in working memory. Tunmer and Hoover (1992) referred to research by Liberman and Shankweiler, claiming that poor readers are unable to access the phonological component of working memory efficiently due to slow word reading. McDougall et al. (1994) reviewed research into the *phonological similarity effect*, which describes the phenomena that good readers recall lists of phonemes or words that don't rhyme (e.g. /f/, /m/, /o/, /i/ and /z/), better than lists of phonemes or words that rhyme (e.g. /c/, /b/, /d/ and /g/). Poor readers, on the other hand, show no difference in recall between non-rhyming and rhyming lists. McDougall et al. found that good readers who were presented with phonologically similar and dissimilar lists of words had better recall for the phonological elements of the lists than did poor readers.

It may appear that phonological awareness skill and verbal working memory are interdependent processes, however, it has been shown that each has a unique contribution to make to the reading process. Hansen and Bowey (1994) conducted a study with 68 second-grade children that examined the contributions of phonological awareness skill and verbal working memory to reading ability. They used three measures of reading ability, a measure of phonological awareness, and a measure of verbal working memory with a multiple regression analysis, to determine the contribution of each factor to reading ability. The results indicated that while verbal working memory and phonological analysis skills share a substantial amount of common variance, they actually tap different reading skills. The phonological analysis scores were found to relate strongly to nonsense word reading and contributed unique variance to word attack scores. Verbal working memory accounted for unique variance in reading measures relating to comprehension.

2.2. Short-term Memory

To understand the relationship between memory for verbal information and phonological awareness more succinctly, it is necessary to examine a model of memory that relates to the processing of phonological information. Atkinson and Shiffrin's (1968) information processing model provides a clear description of the processing of verbal information. It states that incoming images are registered in the brain on the sensory register. Solso (1998) described the brief persistence of visual impressions and their availability for further processing as iconic memory. He suggested that iconic memories disappear quickly (after several hundred milliseconds) if they are not transferred to the short-term store for further processing. Information in the short-term store can be retained for up to 30 seconds, but it will be lost through decay unless it is rehearsed and retained, for storage in the long-term memory. Information in the long-term store can be retained as permanent memories.

Since the development of Atkinson and Shiffrin's model, memory has been studied extensively. Nairne (1996) describes the short-term memory as the conscious or active contents of the mind, which are the end results of perceptual analysis. The short-term memory can activate information that is stored in long-term memory, and also information in the sensory store that has recently been perceived through the senses. This information is then used in the complex cognitive processes involved in human functioning. There are several forms of short-term memory: verbal, visual, haptic, spatial, kinaesthetic and abstract proposition (Massaro & Loftus, 1996; Pashler & Carrier, 1996), and each stores different information. The kinaesthetic short-term memory stores information gained through movement of the body, while spatial short-term memory stores information about the location of objects within the visual field. Verbal short-term memory includes memory for lexical information and incorporates all aspects of phonological memory (Pashler & Carrier, 1996). Gathercole and Baddeley (1989) stated that verbal short-term memory is of particular importance in the acquisition or speech and reading, and in the transfer of phonological information to the long-term store (the lexicon).

2.2.1. Working Memory

Working memory is defined for the purpose of this study, as the mechanism that selects short-term memories and actively maintains and manipulates them to complete various cognitive processes (Baddeley cited in Nairne, 1996. p. 101). With this definition in mind, working memory can be described as a function within short-term memory. Baddeley and Hitch's (1993) classic model of working memory has been refined and updated since it was first presented in 1974 and researchers suggest that it has theoretical limitations. Nairne (1996) has suggested that the model can be "reasonably questioned" and that "further refinements are clearly needed", while Gathercole (1997) argued that several well-researched components of short-term memory (lexicality and long-term learning) are not well explained by the working memory model. Despite these limitations, the working memory model is used in the current study as it provides a clear structural base for understanding the processes involved in accessing phonological information.

The working memory model consists of three elements: the central executive, the phonological loop and the visuo-spatial sketchpad (Figure 2.1). Each will be discussed with a focus on reading skills.

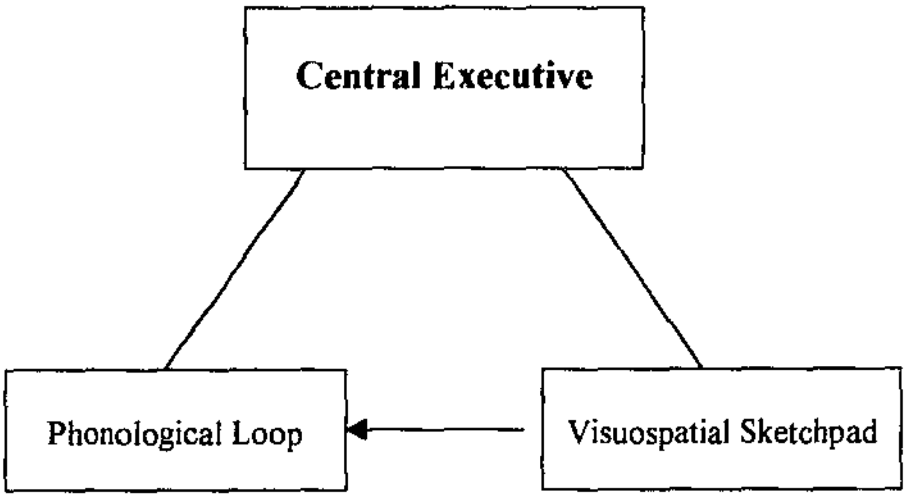


Figure 2.1 The working memory model

The central executive, the device that facilitates most cognitive tasks, incorporates "the processing and storage of information, the regulation of the flow of information through the working memory system, and the retrieval of information from other memory systems" (Gathercole 1997, p19). Nairne (1996, p 108) described the central executive as a "main controller" that "handles and controls on-line processing". He stated that the central executive has received the least attention by researchers but it is assumed to be the vehicle of most cognitive processes. It manages and directs the flow of information in working memory and directs the operation of the visuospatial sketchpad and the phonological loop. In reading, the central executive mediates the flow of phonological, lexical, grammatical and semantic information required for decoding a piece of text. Just and Carpenter (1992) described central executive function as a "pool of operational resources that … generate the intermediate and final products" of reading. (p. 122)

The second component of working memory is the visuospatial sketchpad. The visuospatial sketchpad stores both visual images and spatial images (Nairne, 1996). Current research does not give much indication regarding how the visuospatial sketchpad actually works, especially with regard to storage capacities and forgetting properties. Cooper and Lang (1996) suggested that images in the visuospatial sketchpad function like pictures of the external objects they represent, and they reviewed the work of Shepard and Metzler that confirmed these mental images could be rotated, which explains why some children experience letter confusion between visually similar letters. Visual representations of written words that are in the visuospatial sketchpad can be transferred to a phonological form and retained in the phonological loop for use in reading.

The third component of working memory is the phonological loop, which consists of an articulatory control or "inner voice", and a phonological short-term store or "inner ear" (Nairne, 1996, p 109). The articulatory control is described as having two functions. The first controls the rehearsal process that prevents the decay of material. The second translates visually represented material, such as pictures and printed texts, into phonological form so that they can be held in the phonological store (Gathercole, 1997). This is a vital function, as the dominant format for short-term memory traces has been found to be sound based, or phonological (Nairne, 1996). Thus visually presented verbal material is recoded into a phonological format before it is retained in the phonological store, while speech, which is already in a phonological form, gains direct access to the phonological store (Gathercole, 1997). When the spoken word "cat" is heard, it is registered immediately in the phonological store. When an unskilled reader sees the written word "cat", it is registered in the visuospatial sketchpad prior to it being recoded into phonological information and stored in the phonological store. Thus it can be seen that speech can more easily be recoded than written information, because it requires fewer representations within working memory before being recorded in the phonological store.

Information can be retained in working memory for only about two seconds before decay begins (McDougall et al., 1994). To retain information accurately and for extended periods, the working memory must activate a procedure that will facilitate retention. The articulatory control sends a message to the phonological loop to rehearse and refresh the original representation through the process of sub-vocal articulation. The more information that can be encoded and rehearsed, the greater the memory capacity (McDougall et al., 1994). Gathercole (1997) suggested that the main function of the phonological loop (shown in Figure 2.2) is the prevention of decay or fading of

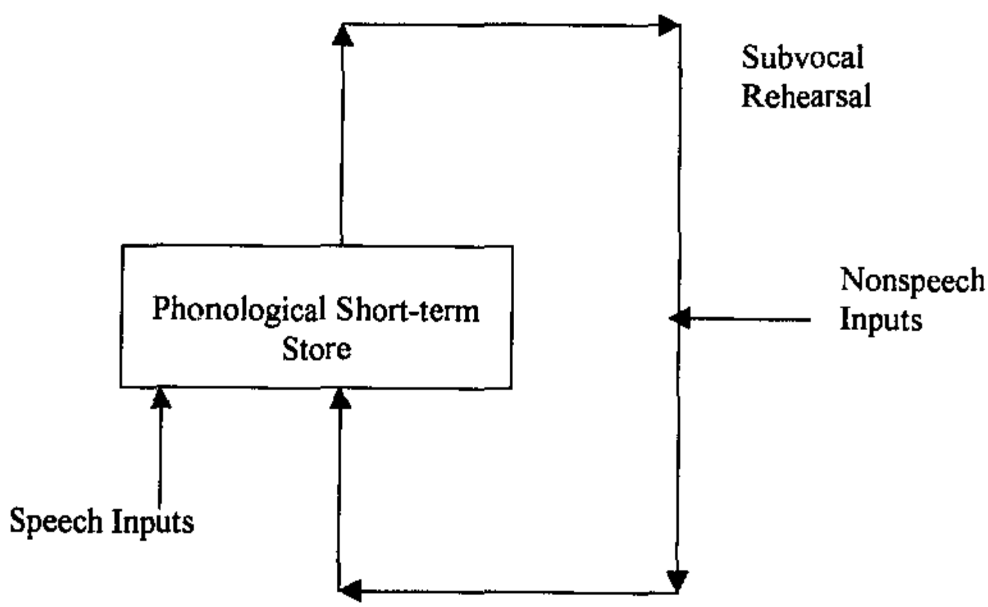


Figure 2.2 The phonological loop model (Gathercole, 1997).

information. The prevention of decay is necessary to the reading process. The phonological loop retains information that has been deciphered from written symbols in a phonological form while readers "construct and integrate ideas from a stream of successive words in a text" (Just & Carpenter, 1992. p. 122).

Hansen and Bowey (1994) suggest that spontaneous use of the rehearsal processes of the phonological loop does not occur until 8 years of age. Thus, younger children may find it more difficult to retain phonological information in working memory than older children. It has also been found that children find it easier to recall lists of short words (such as sit, dog and pat) than longer words (such as mechanism, department and hospitality). In fact, most readers find that lists of long words are harder to recall than lists of short words. This is because long words take longer to articulate and are more likely to be lost through decay between successive rehearsals in the phonological loop. This is described as the *word length effect* (Baddeley &Hitch, 1993; Gathercole, 1997). Adequate storage capacity in working memory is necessary for readers to the retain information about new words long enough to make sense of a piece of text.

With the working memory model in mind, it could be suggested that reading difficulties might result from variations in the function of any of the three component systems. Hansen and Bowey (1994) stated that differing memory capacity relates to the quality of phonological representations that can be produced by the reader. Tunmer (1992) suggested that the phonological loop of each reader has a unique speed, and that this speed relates directly to the amount of verbal information that can be retained in working memory. Ackerman and Dykman (1993) suggested that variations in overall verbal memory storage capacity be explained in terms of developmental delays (caused by chronological factors or disabilities). A defensible model to account for the way individual differences in working memory affect reading comprehension was put forward by Just and Carpenter (1992) and refers to functions of the central executive.

2.2.2. Individual Differences in Working Memory

Just and Carpenter (1992) proposed a model named *capacity constrained comprehension*, which describes the storage and processing functions of working memory in language comprehension. They explained that working memory is activated when individual elements are encoded. These elements may be processing units of cognitive functioning, or storage units for information such as written words, phrases or propositions. Each element must achieve a certain threshold level to become part of working memory. The threshold describes the minimum level of input that is required to activate an element in working memory. One of the ways that the threshold of elements is reached is through *production rules*. Production rules are described as expectations of what elements will be activated next (e.g. in the sentence "The dog ate his bone", it becomes reasonable to assume, by the time you reach the word "his", that the next word will probably be either "bone" or "food"). In this way, activation is propagated from one element ("dog") to the next ("bone"). If there are a lot of production rules being triggered (e.g. when a text is difficult or in an unfamiliar style), there is a lot of potential activation occurring in the system. Should the amount of activation occurring in working memory exceed the system's overall capacity, some elements that have been stored early in a sentence will be replaced by new elements that have just been activated.

Children with limited phonological awareness and phonemic awareness may need to activate a lot of elements in working memory for cognitive processing and storage, as they attempt to decipher unfamiliar words. They may need to recall the sounds corresponding to the letters in a word before they can decide what the word means. Furthermore, incomplete knowledge of grapheme-phoneme correspondences may lead to the activation of a number of words other than the one written. For example, "lame" may activate "lane", "tame" and "fame" in working memory, as well as "lame" itself (see Figure 2.3). Children may need to activate phonics rules relating to digraphs and letter blends, and spelling rules for unusual letter combinations. As a result, there would be a lot of activation in the working memory system. The result

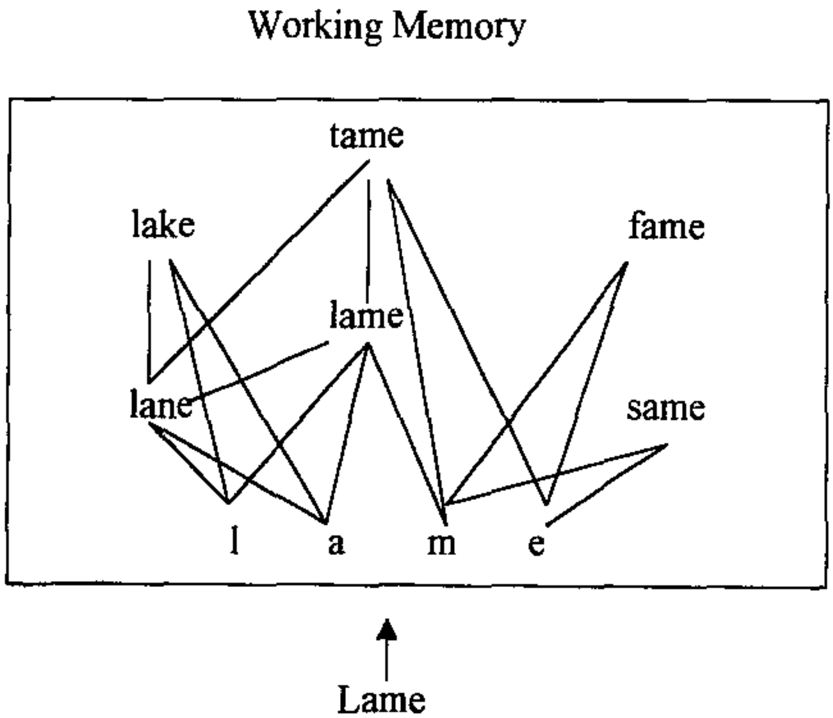


Figure 2.3. Activation of decoding elements in working memory.

being that working memory representations constructed early in a sentence may be forgotten by the time they are needed later in the sentence. The overall effect on memory would be that there would be less capacity available to remember the words in a sentence and to comprehend the message of the text. The capacity constrained comprehension model provides theoretical grounds for concluding that differences in working memory storage capacity exist, and that for people with reading disabilities, deficits in working memory play a major part in reading comprehension and decoding.

2.3. Written Language and Reading

Henderson (1982) suggested that all written languages, no matter what kind of symbols they use to represent speech, are based on phonetic notation. He maintained that written language differences are due to the size of the unit of speech that each written symbol represents. Some ancient American Indian writings (petroglyphs) represent whole sentences or ideas with a single symbol, while Chinese symbols (logographs) represent a concept or relationship (Spector, 1995). Egyptian pictographs represent single words and Hebrew symbols represent syllables (Ben-Dror, Bentin & Frost, 1995). In alphabetic notations, letters, or clusters of letters, are used to represent smaller units known as phonemes. It is apparent that readers of alphabetic notations must learn the meaning of the smaller units of written language and link this information together, to extract meaning from a text. Readers of languages that represent larger units of meaning with a single symbol, can extract a meaningful message from fewer written symbols.

Byrne (1992) compared English readers to Japanese readers and noted that there are fewer reading problems in Japan where individual symbols represent words and concepts. He also found that children with reading difficulties in English can rapidly learn Chinese symbols, and suggested that English notation is quite difficult to learn compared to other written languages because the symbols of the alphabet represent a comparatively small amount of the phonological information. The process of learning to read alphabet notation is apparently quite difficult. This is because reading is the product of decoding and comprehension (Gough, Juel &Griffith, 1992). Readers of alphabetic notation must first decode arrangements of letters of the alphabet to identify words in print, and then apply cognitive processes to comprehend the overall message of the text.

Learning to decode written words, is achieved in stages (Ehri, 1992). Children first begin to read logographically (Ehri cited in Spector, 1995). In logographic reading, children use environmental and visual cues, rather than sound structure, to identify words. The reading of well-known signs and symbols in the environment is an example of logographic reading e.g. "Macdonald's", "STOP" and "Coca-Cola" (Spector, 1995). Inexperienced readers are able to read familiar environmental signs and advertising logos by memorizing distinguishing features of the words. Logographic readers however, are unable to identify these words when they are presented in typed fonts or out of their usual context (Ehri, 1992). Spector (1995) stated that many logographic readers are not able to isolate individual sounds within spoken language. To progress from logographic to phonetic reading, students must develop phonological awareness and be taught phonemic awareness through specific reading instruction.

Phonetic reading involves knowledge of the sounds heard in spoken words and the letters in their written representation (Goswami & Bryant, 1992). Children become competent phonetic readers as they develop spelling skills and learn phoneme-grapheme correspondence. At first, developing readers look for phonetic cues to assist in identifying the words e.g. initial consonants. They then proceed to learn phoneme-grapheme correspondence to enable them to break words into sound components and also to blend sounds together to make up words. Phonetic readers eventually recognize that each sound in a word is represented by letters and groups of letters (Ehri, 1989).

Phonetic reading is not the only skill required for proficient reading because many anomalies exist in letter sound representations that do not follow phonics rules. Consider the letters that can be used to represent the sound /ē/ as in "been", "meat", "seizure" and "happy". Phonemic awareness alone, does not provide sufficient information to decode these variations, and knowledge of spelling rules is necessary (Ehri, 1989). Spelling rules are the consistent letter patterns that are used to represent phonemes in written language. Experienced readers employ their knowledge of spelling rules and memory for irregularly spelled words (lexical knowledge) to read complicated texts (Ehri, 1989). This knowledge describes the third decoding stage, which is orthographic reading (Henry, 1994). Orthographic readers are skilled readers who have learned the phoneme-grapheme correspondence rules and have memorized the spelling rules for irregularly spelled words in the English language. These readers perform significantly better than phonetic readers when decoding (Ehri, 1992). Orthographic reading leads to an ability to read complex and unfamiliar words (Gough et al., 1992).

Orthographic readers do not decode each word phoneme by phoneme because they are able to tap directly into the lexicon when reading known words. They are also able to read irregular words (e.g. "yacht", "island", and "sword".) by sight, without initiating phonemic recoding because spellings for irregular, frequently used words are also stored directly in long-term memory. To read unfamiliar words and words that do not follow usual phonetic conventions, orthographic readers create a visual image in the visuospatial sketchpad that is immediately converted to a phonological representation. This is stored, while the appropriate pronunciation is retrieved through links to long-term memory. Ehri (1992) described this process as the creation of "visual-phonological connections" between spelling rules and pronunciation rules, that enable proficient readers to read unfamiliar words which have not yet been stored in long-term memory.

In comparison to orthographic readers, phonetic readers and readers with disabilities, have a limited lexicon and rely heavily on decoding to determine word meanings. They continue to decode each word phonetically by activating the phonics rules and the letter–sound knowledge that is available to them. This is a repetitive process that puts great demands on the overall storage capacity of working memory. Elements of storage are dropped off to accommodate new processing elements when the system reaches maximum capacity. This limits comprehension and compounds the challenges faced by poor readers due to problems associated with phonological knowledge, phoneme-grapheme correspondence, the lexicon and knowledge of spelling rules.

Studies have shown that remedial students can be taught skills and strategies that will enable them to compensate for some of the difficulties they face. They can be taught to recognize task demands in various subjects and to use appropriate strategies to facilitate task completion (Hollingsworth & Woodward, 1993; Wheldall, Hotchkis, Thompson & Kent, 1992). Children can be taught to be aware of the cognitive processes they perform while learning (Brown, 1985), and can be encouraged to use strategies that will improve their performance.

2.4. Metacognition

Students can enhance their learning through the use of metacognitive skills and strategies. *Metacognition* is knowledge about one's thinking, and control over one's thinking and learning activities (Baker & Brown cited in Brown, 1985. p. 501; Swanson, 1990). Control over thinking and learning in reading, involves reflecting on one's own "cognitive processes" and being "aware of one's own activities while reading" (Brown, 1985, p. 502). This allows the reader to modify their cognitive processes to ensure that maximum comprehension is achieved, or that a set task is completed. This involves the conscious application of reasoning and deductive activities that facilitate complex reading skills (e.g. decoding difficult words, remembering syntactical and semantical information, and the integration of new information with existing knowledge).

The ability to perform metacognitive activities to enhance learning has been seen as a contributing factor in determining the difference between learners. "Good learners are described as those who have gained conscious control of their planning and learning activities whereas poor learners are less spontaneous and less flexible" (Chan, 1991, p. 4). While not all children use metacognitive strategies, research has shown that many students can be taught to use them, regardless of cognitive ability. Borkowski (1992) summarized three articles on the enhancement of academic performance. He suggested that students with learning disabilities could be taught to search for appropriate strategies to use in learning situations and that self-regulation and the motivational beliefs associated with strategy use, are the prominent concepts behind metacognitive theory and learning disabilities. Borkowski maintained that increased motivation and personal belief systems regarding successful learning contributed to the success of children with learning problems.

Swanson (1990) found that use of metacognitive strategies dramatically enhanced student performance regardless of aptitude. He conducted a study with 31 high-aptitude and 25 low aptitude students, who were sub-grouped according to metacognitive ability. All participants were administered two problem solving tasks. The results showed that students with high-level metacognitive skills and low academic ability performed significantly better than students with low level metacognitive skills and high aptitude for learning.

It is evident that metacognition assists the performance of students with learning disabilities across a wide range of subject areas. Wheldall et al., (1992) taught self-monitoring techniques to a class of ten students with learning disabilities, with the result that on-task behaviour increased by 10%. Savage and Lombardi (1993) suggested that higher order thinking skills could be taught to increase decision-making and problem solving in disabled learners. Hollingsworth and Woodward (1993) taught problem-solving strategies, through a computer simulation, to a group of 37 secondary students with learning disabilities, and found that the group performed significantly better on a task relating to health facts and concepts. Chan and Cole (1986) conducted a study of 36 children with reading disabilities and 36 regular class children, aimed at teaching metacognitive skills to enhance reading comprehension. They assigned children from each group to one of four training methods (three were metacognitive methods and the fourth was a control condition). It was found that the children with reading disabilities in each of the three metacognitive training methods, performed significantly better that those in the control group. The regular class students showed no significant differences across training methods indicating that they were possibly already using metacognitive strategies. The results of this research indicate that students with learning problems can be taught to use metacognitive strategies that will improve their learning performance. They become active learners who plan, monitor, test, revise and evaluate how to achieve a learning outcome (Brown, 1985).

2.5. Reading Disability

Researchers have found the students with reading disabilities often have significant deficits in orthographic reading skills (Bowe, 1995; Ehri, 1989; Henry, 1994; Korhonen, 1995; Perfetti, 1986). Many reading disabled students do not become orthographic readers. They experience problems in performing tasks such as systematically checking spelling and phonics rules and lexical information on class charts, which would assist them to remember the phonological properties of words (Liberman & Shankweiler, 1991). Children with reading disabilities may be able to demonstrate substantive listening comprehension through direct access to the phonological loop. Unfortunately this is no guarantee of effective knowledge of phoneme-grapheme correspondence rules and working memory processes, associated with the transfer of information in the visuospatial sketchpad to the phonological store. Therefore, reading comprehension remains weak. Sight words are not committed to memory despite being seen numerous times and these readers do not spontaneously develop strategies for decoding unknown words (Henry, 1994).

Some of the indicators that a child has the potential for reading disability are evident in the pre-schools years. Typical areas for concern are disinterest in reading activities; difficulties with rhyming activities and word games; trouble learning the alphabet; difficulty with syllabification and blending (Henry, 1994).

When formal reading instruction commences, other deficits become apparent, the most consistent of which appear to be at word level. Gough and Tunmer (1986) stated that word recognition problems occur if students fail to learn basic alphabet orthography and the letter-sound correspondence rules. For some children, the visual similarity of letters is an enormous challenge (Mauer & Kamhi, 1996). Others may experience great difficulty as they read and write words. They may omit letters or syllables, mispronounce words and phonemes, and substitute letters or words (Henry, 1994). Henry also suggested that some developing readers may find it difficult to grasp concepts of word structure (syllables, prefixes, suffixes and roots within words). It is apparent that students with reading disabilities face the likelihood of a complex set of difficulties associated with representation of text material in working memory. The result of these difficulties is seen in poor comprehension (Tunmer & Hoover, 1992).

2.6. Nonsense Words and Strings

A significant correlation exists between reading skill and the ability to read nonsense words (Gathercole & Baddeley, 1989; Gough, et al., 1992). This is because decoding pronounceable nonsense words requires phonological knowledge (Siegel & Ryan, 1988), and adequate working memory (Ackerman & Dykman, 1993). Gough and Tunmer (1986) explained that tests involving nonsense-words or strings (including pronunciation and silent comprehension) are the most precise measure of decoding skill because they minimize the advantage that good readers may have over poorer readers, due to their wider experience with print. Tests of nonsense words may focus on the accuracy (e.g. Tunmer & Nesdale cited in Tunmer, 1992) and speed (Perfetti & Hogaboam cited in Shankweiler, 1992) of naming the words.

Tunmer (1992) stated that nonsense word tests require the recall of strings of digits, letters, or nonsense syllables or words (e.g. "toin" and "sark"). He found that knowledge of phoneme-grapheme correspondence rules is closely related to reading ability, and that speed and accuracy of naming nonsense words or strings is an accurate indication of differences between good and poor readers. When confronted with nonsense words, children of average reading ability use their knowledge of phoneme-grapheme correspondence to assign an acceptable pronunciation to the nonsense string. Children with reading disabilities however, may have limited decoding skills and consequently find that decoding pronounceable, short nonsense words is a difficult task.

The ability to decode nonsense strings does not necessarily depend on intellectual ability. Ackerman and Dykman (1993) conducted a study of the relationship between reading ability, phonological processing skills and intellectual ability. They investigated the skills of three different groups: a group of 42 disabled readers of normal IQ, a group of 56 average readers of average IQ, and a group of 21 poor readers with low IQ. Measures of phonological processing and memory were administered to each group. The results showed that the best single predictor of reading level was nonsense word reading, regardless of ability. Manis and Morrison (cited in Tunmer & Hoover, 1992) compared the nonsense word reading of a group of young average readers who were matched by mean reading age to a group of older students with reading disabilities. They found that normal ability readers did better than poor readers, and that the older poor readers scored significantly lower than the grade two average readers. It is evident that nonsense word reading is a stronger indicator of reading ability than intellectual ability, and that extends across different age groups.

The current study also incorporates a reading level match design. The reading level match design compares groups that are matched according to reading age, rather than comparing groups of children of the same age with differing levels of reading ability. It might be reasoned that groups of children of the same mean reading age and different chronological ages are able to achieve a similar standard of skill development (e.g. phonological awareness or word attack skills). But the research shows that this is not necessarily so, and that children with reading disabilities may demonstrate skill deficits when compared to average readers, despite being matched for reading ability (Felton & Wood, 1992). Differences between the groups can indicate specific problem areas for the child with reading disabilities, and also strength areas that assist the child to compensate for skill deficits (they may be better than the average readers at some skills). On the other hand, in a study that compares groups of children of the same chronological age and varying ability levels, it is likely that the children with reading disabilities are significantly weaker than the average readers, in many skill areas.

In the current study a group of middle and upper primary students were tested for reading ability, and a mean reading age was calculated. A group of younger students, with average reading ability, was then selected so that the mean chronological age, and reading age, that was similar to the mean reading age of the older students. It was assumed that the average readers would have developed their reading skills along a standard developmental continuum, and that variations between the two groups would identify specific weaknesses and strengths in the group with reading disabilities. A task was designed that required the participants to view nonsense strings, and then physically reproduce the strings, rather than read them aloud. The consonant blends of the nonsense strings in the current study were extremely difficult to pronounce (e.g. "bdoi". "eidb"). Participants were required to retain the arrangement of the nonsense string in memory and then present that arrangement using blocks. It was anticipated that there would be differences between the two groups in their ability to remember the nonsense strings.

2.7. Letter Reversals

Young and inefficient readers may experience decoding difficulties due to problems associated with recall and visual perception. They may have problems remembering letter shapes and the location of the curves, loops and strokes in each letter. Typical error patterns that children experience in learning alphabet orthography relate to reversals (b/d, p/q/ and p/g), inversions (m/w and b/p) transpositions (was/saw), rotation (as in b/p) or phoneme confusion. Letter confusions involving b, d, p and q, are also most comm ι errors (Harris & Sipay, 1975). There is little indication in the research that older students, with reading disabilities, experience perception problems. Therefore it was decided to incorporate in the current study reversible letters, that have been identified as a problem for younger readers, to investigate whether they continue to be a problem for older children with reading difficulties. The letters /b/ and /d/ were chosen to be included in the nonsense strings in the current study, to determine whether letter recall is a factor for one group more than the other.

the current study, to determine whether letter recall is a factor for one group more than the other.

2.8. Vowel Location

The position of individual letters in words affects readability (McBride-Chang, 1995). Treiman (1992) suggested that readers found it easier to pronounce vowel / final consonant rimes (e.g. "at". "ish") than initial consonant / vowel rimes (e.g. "way", "blue"), as these types of rimes have relatively consistent pronunciation in the English language. Thus, readers would find it easier to pronounce VC or VCC nonsense speech segment than CV or CCV nonsense speech segments.

The location of consonants within words affects readability. Unfamiliar consonant blends that do not represent single phonemes, are most easily and logically pronounced as two syllables rather than one (e.g. /wb/, /mt/ or /bp/). Treiman (1992) suggested that it was easier for children to read initial consonants than final consonants, in words of one syllable, and that initial consonant clusters were quite difficult to pronounce. Stanovich (1992) found that poor readers responded correctly to initial consonants 90% of the time and yet made consistent errors with the same consonants when they were placed at the end of words.

Certain groups of letters tend to behave as units within words (e.g. /sh/, /ch/ and /th/), and are pronounced as a single unit of sound. Readers become familiar with these letter combinations and recognize them readily. When CCV letter combinations are not consistent with familiar phoneme blends, they create challenges for readers at all levels, but they are especially difficult for students with reading disabilities. Treiman (1992) suggested that "nonsense words are pronounced by activating and synthesizing the pronunciation of similar known words". Thus the word CVCC nonsense word "kish" is pronounced by combining the onset /k/ as in kitten with the rime /ish/ as in fish and producing a word that rhymes with /fish/.

This study includes CVC, CCV and VCC nonsense strings to determine whether any of the vowel locations is easier to remember. The consonants /b/ and /d/ are used with the result that phoneme blends /bd/ and /db/ will be created in the CCV and VCC strings. Students may try to read some of the nonsense strings as monosyllabic units, but it is more likely that they will attempt to read the blends as two separate syllables.

2.9. Space Location

A speech stream contains no designated word boundaries, and spectrogram studies show that physical breaks between words cannot be identified (Henderson, 1982). When young children listen to speech they perceive that boundaries between words in a speech stream are located at the end of an instruction or statement, or when a breath is taken. The more experience a child has at listening to and interpreting speech, the more able he or she is to break speech up into smaller fragments. For example, the speech stream "sit in the chair" can eventually be perceived as individual units of meaning ("sit", "in", "the" and "chair"). When children are confronted with the language of print they begin to realize that there are spaces between written units of meaning (words). These spaces soon come to represent word boundaries, and children recognize that they are as important to a text as the letters in the words because they mark the end of one word and the start of the next. The current study has included space markers, to give the participants the impression that the nonsense strings were words, or complete units to be considered as a whole.

2.10. The Current Study

The current study examines the performance of students with reading disabilities and students of average reading ability, in a task involving working memory for nonsense strings. A task was prepared that consisted of nine nonsense strings, each with three phonemes, which were arranged on wooden blocks and viewed by each participant for two seconds. The blocks were concealed behind a screen and then rearranged to form a new nonsense string. Students were then shown the new nonsense string and instructed to place the blocks into their original order. The task incorporated differences in vowel location and blank space blocks. The independent variables examined in the study were group differences (a group with reading disabilities and a group of average readers), vowel location (CVC, CCV and VCC) and space location (XX - - -, X - - - X, and - - - XX). Phonological ability was introduced as a covariate so that the effects of individual variation in phonological awareness levels could be examined. Error in positional recall of nonsense strings was the dependent variable.

2.11. Research Questions

The study was designed to answer several research questions.

1. Will there be a significant difference in the recall of nonsense strings between students with reading disabilities and students of average reading ability?

2. Will there be a significant difference in recall of nonsense strings that differ in the location of vowels?

3. Will there be a significant difference in recall of nonsense strings that differ in space location?

4. Can any of these differences be accounted for by the children's phonological ability?

5. What differences in strategy use exists between students with reading disabilities and students of average reading ability?

CHAPTER 3

METHOD

This chapter contains the participant selection criteria, and the design of the study is explained. The test instruments that were used are discussed and the testing procedures are itemized.

3.1. Participants

The participants of the study were two groups of children from the Perth metropolitan area. One group consisted of 24 Grade 2 and 3 students, of average reading ability, whose mean chronological age matched the mean reading age of the second group. Each participant in this group was given the Peabody Picture Vocabulary Test-Revised (PPVT-R), a norm-referenced test of general verbal ability (Dunn & Dunn, 1981); the Neale Analysis of Reading Ability-Revised (RNARA), a test of reading ability (Neale, 1988); and the Auditory Analysis Test (AAT), a test of phonological ability (Rosner & Simon, 1971). To be admitted to the study, students were required to perform within the normal range on the PPVT-R. No upper limit was put on their reading age but the lower limit was set at less than 12 months lower than the chronological age. The mean chronological age of this group was 8 years 10 months and the mean reading age was 8 years 3 months. Group members were selected from diverse socio-economic backgrounds within the Perth metropolitan area.

The second group consisted of 24 students with reading disabilities, from Grades 4 to 7. For the purpose of this study, a child with a reading disability is described as a child of average intelligence, whose reading age is two years below his or her chronological age. This group was taken from a pool of students identified by schoolteachers, teachers from remedial reading clinics, and members of the Dyslexia SPELD Association of Western Australia. Students were admitted into this group if they met two criteria. First, they were required to have a reading age that was more than two years behind their chronological age, and secondly they were required to score within the normal range on the PPVT-R. The mean chronological age of this group was 10 years 8 months, and the mean reading age was 8 years 3 months.

Table 3.1 shows details of the two groups, including the results of the reading test, the test of general verbal ability and the test of phonological ability.

Table 3.1

Mean chronological and reading ages, mean PPVT-R scores, mean AAT scores and the sex ratio in each group.

	Group 1		Group 2	
	M	(SD)	M	(SD)
CHRONOLOGICAL AGE	8:3	(0:5)	10:8	(1:1)
READING AGE	8:10	(0:7)	8:3	(1:1)
VERBAL ABILITY	101	(9:1)	98	(8:2)
PHONOLOGICAL AWARENESS	23	(7:6)	19	(8:5)
MALES: FEMALES	12:12		16:8	

3.2. Design

The study employed a factorial design to allow the concurrent manipulation of several independent variables (Keppel & Zedeck, 1989). The design was a 2 (group: reading disabled, and average ability readers) x 3 (vowel location: CVC, VCC and CCV) x 3 (space location: XX letter string; X letter string X; and letter string XX) design. Group was the between-subjects variable. Vowel location and space location were within-subjects variables and related to the Test of Short-term Memory for Nonsense Strings, which is described below. The participants were required to reproduce the order of nonsense strings by manipulating blocks upon which letters and vowel blends were typed. Errors in positional recall of letter and space elements comprised the dependent variable. Phonological awareness was included as a covariate.

3.3.Instruments

Four test instruments were used in the study. Three were published tests: the Revised Neale Analysis of Reading Ability (Neale, 1988), the Auditory Analysis Test (Rosner & Simon, 1971) and the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981). The fourth test, the Test of Short-term Memory for Nonsense Strings was devised for the study. Each of these is described in turn.

3.3.1. Revised Neale Analysis of Reading Ability (RNARA)

The Revised Neale Analysis of Reading Ability was administered to determine whether or not the participant met the reading age criteria. The RNARA has three presentations: two forms and a Diagnostic Tutor. Each form consists of six short, graded passages of text each with an accompanying line drawing. All of these are bound together into a book. The RNARA has been norm-referenced for Australian children in grades 1 to 6. The reliability and validity of the test is well established with an internal consistency for accuracy of .81 (Neale, 1988). Form 1 was administered to each participant, and scores for reading accuracy were taken to determine a reading age for each participant.

3.3.2. Auditory Analysis Test (AAT)

The Auditory Analysis Test was administered to determine phonological ability. It is a phoneme deletion test consisting of 40 words of one to four syllables (Appendix A). The test involves the researcher pronouncing a word and then having the person taking the test repeat the word while deleting a given phoneme. The phoneme to be deleted was the initial or final syllable, the initial or final consonant, the first consonant of a consonant blend or the medial consonant or syllable. The range of possible scores was 0 to 40 correct responses. An analysis of the validity of this test by Rosner & Simon (1971) reported that the AAT provided an acceptable and valid method of assessing a child's "ability to sort, order and synthesize the perceptual elements of auditory information".

3.3.3. Peabody Picture Vocabulary Test – Revised (PPVT-R)

The Peabody Picture Vocabulary Test-Revised: Form M was conducted to determine general verbal ability. Each test item consisted of four, black and white line illustrations, arranged in a multiple-choice format. Test items were organized in increasing difficulty and presented in a spiral-bound booklet. Participants were required to select a picture that represented the meaning of a given word. Testing was discontinued when six out of eight consecutive responses were incorrect. The PPVT-R has been norm-referenced and the mean standard score for this test has been established at 100 with a standard deviation of 15 (Dunn & Dunn, 1981). After testing the raw scores were converted to standard score equivalents for the corresponding ages. Children who scored 90 and above (considered to be within the average ability group), were admitted to the study. The validity of this test is well established. Martinson (1973) observed that while the PPVT is not as comprehensive as the Stanford Binet or Wechsler intelligence tests, it is nevertheless quite valuable as a screening instrument.

3.3.4. Test of Short-term Memory for Nonsense Strings (SMNS)

The Test of Short-term Memory for Nonsense Strings was developed for the current study, and consisted of nine test items. It was designed to test the short-term memory of students for unfamiliar strings of phonological information. Each test item was presented as an arrangement of five wooden blocks, marked on one face with either letters or a blank surface. One block was marked with the letter 'b' and another with the letter 'd'. The third block in each test item was marked with one of three vowel blends - 'ou', 'oi' or 'ei'. Bold, lower-case letters were typed on a white paper that was glued onto a block and then covered with clear contact. The fourth and fifth blocks had a blank, white square, glued to a single face of a block (see Figure 3.1).

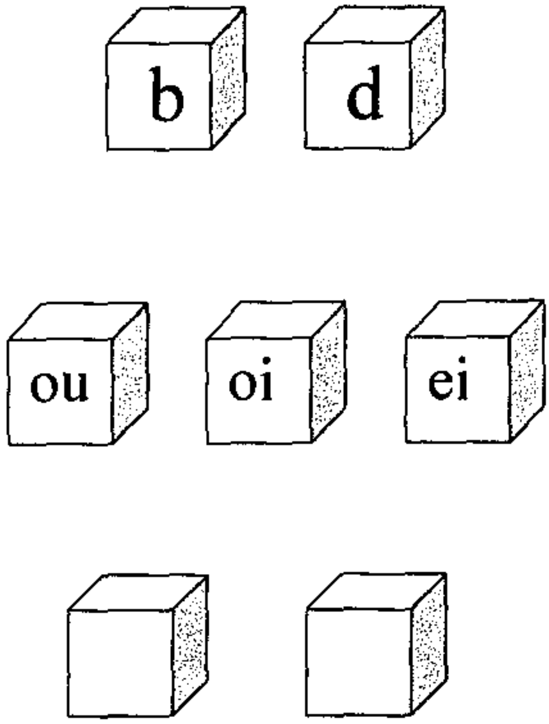


Figure 3.1 Blocks used for Test of Short-term Memory for Nonsense Strings

'b','d','ou', 'oi', 'ei' and 2 blank blocks.

The nonsense strings all contained the letters 'b' and 'd', and one of three vowel blends. The letters were arranged in one of the following patterns: consonant, vowel blend, consonant (CVC); vowel blend, consonant, consonant (VCC); consonant, consonant, vowel blend (CCV). Half the participants in each group were given nonsense strings in which the letter 'd' was positioned before the letter 'b', while the other half of both groups were presented with nonsense strings with the letter 'b' before 'd'. Each of the three vowel blends was used three times in each test and all participants saw all three vowel blends. To maximize randomness of presentation, the vowel blends were placed into the nonsense strings in three different patterns (ou, ei, oi;

ou, oi, ei; and oi, ou, ei). A third of the children in each group were randomly assigned to each vowel blend pattern. The space blocks were arranged in the following ways around the nonsense strings: two spaces at the beginning (XX- - -); a space at the beginning and at the end (X- - -X); and two spaces at the end (- - -XX). Half the participants received nonsense strings with 'b' before 'd' and vice versa, and a third of participants each received one of the three arrangements of vowel blends, therefore there were six different orders of presentation. One of the six orders of presentation is shown in Figure 3.2, and the complete set is found in Appendix C. All participants received three vowel locations and three space locations, regardless of the order of presentation. The nine test items are shown in Table 3.2. They correspond to the 3 (vowel location) X 3 (space location) factorial design described previously.

Item number **Block Arrangement**

1			d	b	ou
2		ei	d	b	
3	oi	d	b		
4		d	ou	b	
5			ei	d	b
6	d	b	oi		
7	d	ou	b		
8			d	ei	b
9		d	b	oi	

Figure 3.2. The test with 'd' before 'b', and vowel blend pattern 1.

Table 3.2

The experimental design of the study: All members of Group 1 and Group 2 were tested on each of the nine nonsense strings in the SMNS test.

Each of the Test Items used for Group 1 and 2

	X - - - X	XX - - -	- - - XX
CVC	XCVCX	XXCVC	CVCXX
VCC	XVCCX	XXVCC	VCCXX
CCV	XCCVX	XXCCV	CCVXX

A single researcher conducted all four tests in a single session that lasted from 30 to 45 minutes (depending on the age and skill of the participant). All the potential participants in the reading disabled group were tested first. Once 24 group members that fitted the selection criteria were identified, the mean chronological age and reading ages were calculated. The mean reading age of the group with reading disabilities (8 years and 3 months) provided a target chronological age for the group of younger students with average reading ability. The sample for group 2 was selected from seven-year-old and eight-year-old students. Participants were tested, and those that met the selection criteria for the average reading group were included in the study.

All responses were recorded in writing on prepared proformas (Appendices D, E, F & G). Everything possible was done to put children at their ease and to ensure that the environment provided minimal distractions. Before testing commenced, each participant was asked two or three general questions about their school or home environment, their family and friends. Participants were reassured that the data being collected would be used to provide information about how people remember the words they read. It was also stressed that all responses were important and that "rightness" or "wrongness" was not the main consideration but rather "how the test was done". Testing in children's homes was conducted at the kitchen table and parents were asked to encourage siblings to play in another room. Testing in children's schools was carried out in an unoccupied room at a desk or table. In the event of interruptions from other students, testing was temporarily discontinued.

3.4.Procedure

3.4.1. RNARA Procedure

The RNARA was conducted according to handbook guidelines. Prior to commencing this test, each participant was given a very simple practice passage to read with four oral comprehension questions to answer. The test then commenced at the simplest level. Participants were asked to read a passage out loud, and errors were recorded in writing. Participants answered eight comprehension questions at the conclusion of each form. Testing took about 15 minutes and ceased after 12 errors in a single passage.

3.4.2. AAT Procedure

The AAT was conducted according to handbook guidelines. At the commencement of this test the researcher showed the participant a picture of a cow and a boy on the paper (Appendix B). The child was instructed to "say cowboy". The cow was then covered and the participant was instructed to "say it without cow". The participant was then shown pictures of a tooth and a brush and instructed to say "toothbrush". The brush was then covered and the participant was instructed to "say it without brush". Testing then commenced on the 40 oral test items using the same wording. Participants who were unable to respond to a particular item correctly were given the complete instruction again. If they responded correctly the second time they received a correct response score, but if they were unable to do so, the item was scored as incorrect. Testing took about ten minutes and was discontinued after four consecutive errors.

3.4.3. PPVT-R Procedure

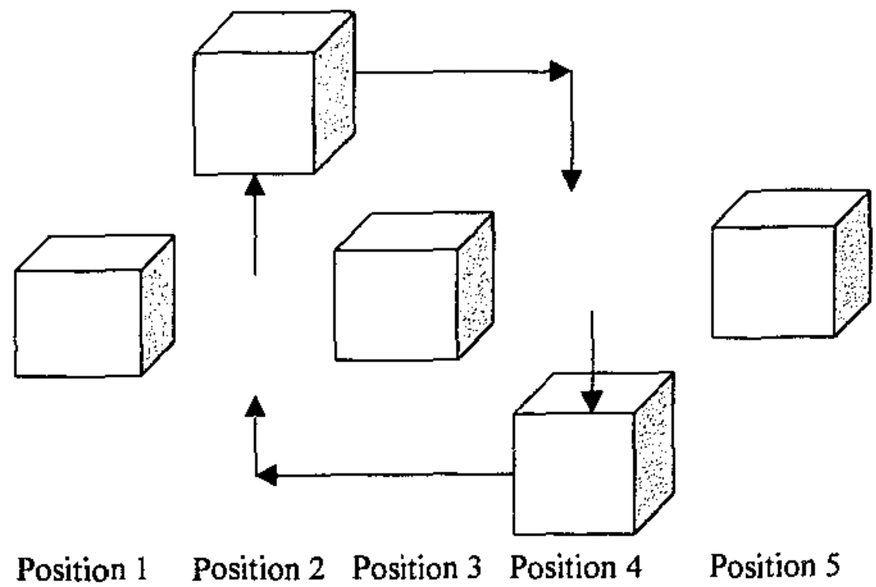
The PPVT-R was administered according to handbook guidelines. Prior to the commencement of testing a simple practice example was given. Formal testing commenced when the participant was successfully able to respond to the practice examples. Testing took about 15 minutes per student and was discontinued after 6 out of 8 consecutive errors.

3.4.4. SMNS Procedure

The test kit was comprised of four sample blocks (marked, 's', 'ai', r' and 'blank'); a white perspex screen 30cm by 20 cm; and the seven test blocks. Each test was conducted according to the following procedures: first, a practice example was given and students were told, "I am going to arrange some blocks with letters on them behind this screen. I will take away the screen and show you the blocks and then I will put the screen back and move the blocks around. Your job is to put the blocks back into the same order that you first saw them. We will do a practice one first". The four practice blocks were arranged behind the screen ('s' 'r' 'ai' and only once space block) and then shown to the participant for two seconds. Only once space block was used in the practice element to reduce confusion and promote a focus of attention on the letter blocks. The screen was replaced and the blocks were quickly arranged as follows (X 's' 'ai' 'r') and placed face down on the desk. The screen was then removed and the student proceeded to arrange the blocks according to the original arrangement and orientation. After the practice example was successfully negotiated, the researcher said, "That was quite simple, wasn't it? Are you ready to do some more?" The test then proceeded as per the proforma, commencing at a randomly selected item number.

The researcher arranged the first five blocks behind the screen and asked, "Are you ready to look," to establish maximum attention. The screen was lifted for two seconds and then replaced. The blocks were quickly rearranged in an established pattern (see Figure 3.3). Blocks in positions two and four were exchanged and the blocks in positions one and two were moved to the right of the block in position five. The blocks were placed face down and the screen was removed and participants were asked, "Put the blocks the way you first saw them". At the conclusion of the test each participant was asked, "What did you do inside your head to remember where the blocks were?" Responses were recorded verbatim, in writing. The test was scored according to the number of errors in block positions. The maximum possible number of errors was 45 (9 x 5) and the minimum was zero.

STEP 1 – Blocks in Positions 2 and 4 are exchanged.



STEP 2 – Blocks in Positions 1 and 2 are placed at the end.

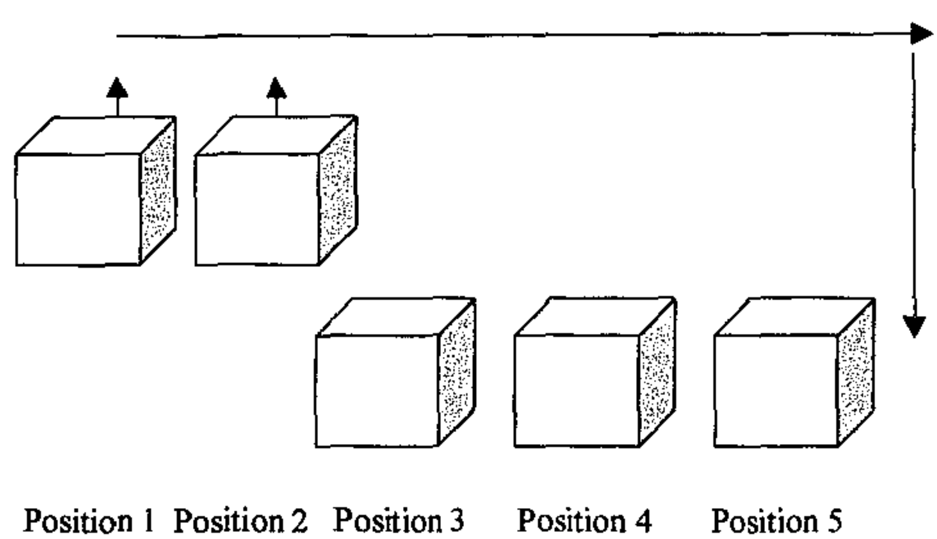


Figure 3.3. The method of rearranging the blocks. **Step1**: blocks 2 and 4 were exchanged. **Step 2**: blocks 1 and 2 were placed at the right of block 5.

3.5. Ethical Considerations

Parents were informed in writing that all original records would be stored in a locked file and that the anonymity of the participants was guaranteed. Before a child was able to participate in the study, their parent or guardian, and principal signed a permission form (Appendixes H & I). Interested parties were notified that copies of the finished thesis would be made available upon conclusion of the research. Participants were quite at ease during assessment and enjoyed being part of the study. Students with reading disabilities, who had generally been exposed to numerous testing and diagnostic procedures, found the RNARA to be a simple, non-threatening reading test. Most participants treated the PPVT-R, AAT and Test of Short-term Memory for Nonsense Strings as puzzles or games.

CHAPTER 4

RESULTS

The scores from each group on the Test of Short-term Memory for Nonsense Strings were analyzed using an analysis of variance (ANOVA). Phonological awareness was a skill that was vital to the completion of the SMNS, therefore it was also decided to conduct an analysis of covariance (ANCOVA) using phonological awareness as the covariate. Verbal reports of the strategy used by each participant to perform the test were recorded. A chi square was conducted to determine whether the differences between groups, in strategies used, was statistically significant. The alpha level for all tests was set at .05. The first section reports the ANOVA results, from interactions to main effects. The second section reports the results of the ANCOVA. The third section reports the result of the chi square relating to the different strategies used to complete the Test of Short-term Memory for Nonsense Strings. The final section discusses the errors made by members of each group with relation to the letters /b/ and /d/.

4.1. Results of the Analysis of Variance

Each child in both groups completed the Test of Short-term Memory for Nonsense Strings (SMNS). An analysis of variance (ANOVA) was calculated for group (reading disabled and average readers), vowel location (CVC, VCC, and CCV) and space location (XX - - -, X - - - X and - - - XX). The results of the ANOVA are presented in Table 4.1. There were no significant interactions, but all three main effects were significant. The means and standard deviations for each cell are shown in Table 4.2, and the significant main effects are described in detail below.

Table 4.1.

Results of the Analysis of Variance

EFFECT	ANOVA RESULT
Main Effects	
Group	F (1, 46) = 11.45, p = .001
Vowel Location	F (2, 92) = 4.88, p = .010
Space Location	F (2, 92) = 3.15, p = .048
Two-way Interactions	
Group x Vowel Location	F (2, 92) = 2.62, p = .078
Group x Space Location	F (2, 92) = 0.14, p = .870
Vowel Location x Space Location	F (4, 184) = 0.93, p = .446
Three-way Interaction	
Group x Vowel Location x Space Location	F (4, 184) = 0.78, p = .540

Table 4.2.

Means and standard deviations in each cell

	CVC	VCC	CCV	Total
Group1: Average Readers				
XX - - -	1.79 (1.96)	2.42 (2.15)	1.79 (1.89)	2.00 (1.41)
X - - - X	2.33 (1.58)	2.21 (1.50)	2.04 (1.43)	2.19 (1.12)
- - - XX	1.54 (1.77)	1.88 (1.65)	1.79 (1.74)	1.74 (1.15)
Group 1 Total	1.89 (0.98)	2.17 (0.99)	1.88 (0.91)	1.98 (0.65)
Group 2: Children with reading Disabilities				
XX - - -	0.92 (1.64)	1.92 (1.84)	1.29 (1.65)	1.37 (1.23)
X - - - X	0.83 (1.55)	1.75 (1.73)	2.21 (1.67)	1.60 (0.90)
- - - XX	0.54 (1.22)	1.04 (1.49)	1.17 (1.61)	0.92 (1.04)
Group 2 Total	0.76 (0.95)	1.57 (1.11)	1.56 (1.06)	1.30 (0.74)
Total	1.33 (1.11)	1.87 (1.08)	1.72 (0.99)	1.64 (0.77)

Note: Mean (Standard deviation)

4.1.1. Group Differences in the ANOVA

The ANOVA yielded a significant main effect for the difference in recall of nonsense strings between students with reading disabilities and students of average reading, F (1,46) = 11.45, p = .001. This result indicates that the group of students with average reading ability made a significantly different number of errors on the SMNS to the group of students with reading disabilities. The mean of total errors for the group with average reading ability (Group 1), was 11.67 (SD =5.6). The mean of total errors for the group with reading disabilities (Group 2), was lower at 8.04 (SD 5.8). Thus the ANOVA yielded the rather surprising result that the older students with reading disabilities were significantly better at recalling nonsense strings in the SMNS than the younger students of average reading ability. The implications of this result will be discussed in chapter 5.

4.1.2. Vowel Location in the ANOVA

The SMNS test included three nonsense strings for each of the three vowel locations (CVC, VCC and CCV) with a total of nine test items (see Appendix C). The ANOVA yielded a significant effect for vowel location and total errors, F (2,92) = 4.88, p = .010. This result indicates that the location of the vowel within the nonsense strings made a significant difference to the number of errors for all participants, regardless of group. The means for errors on each vowel location were calculated out of five possible errors for each test item and are shown in Table 4.2.

The within-subjects contrasts, showed that the difference between the CVC mean and the VCC mean was significant, F (1,46) = 5.90, p = .019, and the difference between the CVC mean and the CCV mean was also significant, F (1,46) = 4.19, p = .046. This result indicates participants found the CVC nonsense strings to be significantly easier to recall than either the VCC or the CCV nonsense strings. Figure 4.1. shows the mean errors for the three vowel locations of each group.

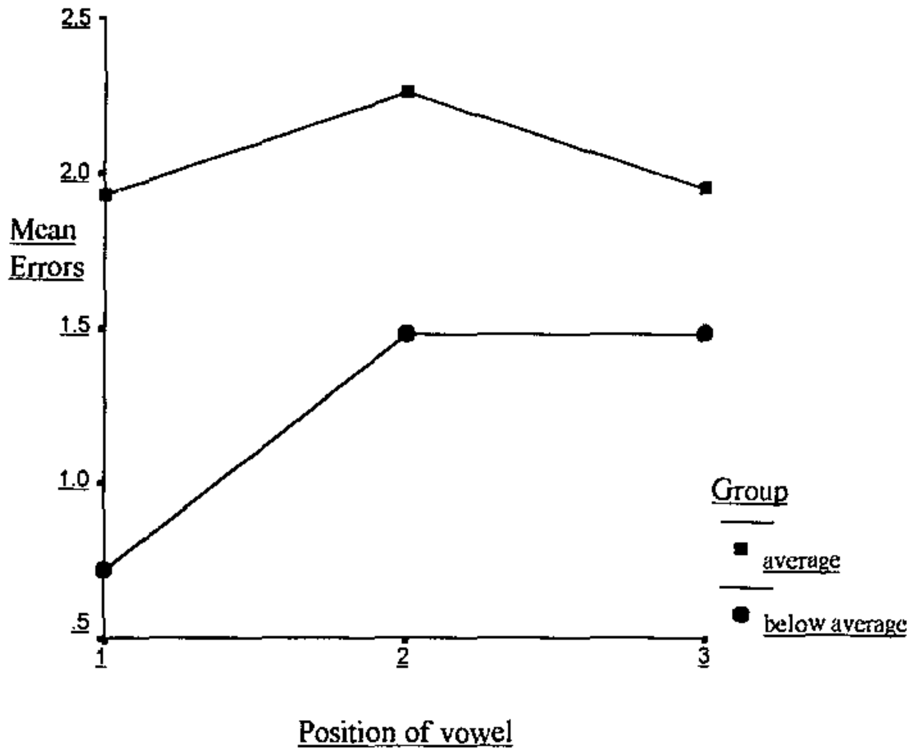


Figure 4.1. The mean errors for each subject group for each of the three vowel positions (1 - CVC, 2 – VCC and 3 – CCV) in the ANOVA.

4.1.3. Space Location in the ANOVA

The SMNS test included three space block locations around the nonsense strings (XX - - -, X - - - X, and - - - XX). The ANOVA yielded a significant effect for vowel location, F (2,92) = 3.15, p = .048. The means for total errors on each space location are shown in Table 4.2. They indicate that both groups made the least errors on the - - - XX space location (space location 3). The within-subject contrasts of the statistical difference between space location 1 errors (XX - - -) and space location 2 errors (X - - - X) was not significant, F (1,46) = 0.94, p = .34. However, the contrast between location 2 and 3 was significant at F (1,46) = 5.66, p = .02. This indicates that there was a significant difference between space positions X -.-.- X and - - - XX.

The means for space location 2 were higher than the means for location 3, indicating that children made the least errors when the two spaces were at the end.

4.2. Results of the Analysis of Covariance

The task in the SMNS depended partly on phonological awareness. To recall the nonsense string, participants may have registered the nonsense string in the visuospatial sketchpad and then recoded the information into phonological form. Some of the children would have rehearsed the phonological information to retain the nonsense string in working memory to complete the task. It was considered that differences between individuals and groups in phonological ability would affect performance on the SMNS, therefore it was decided to partial out this effect using phonological awareness as a covariate.

The phonological awareness of each group was measured using a test of phonological ability, the Auditory Analysis Test (Rosner & Simon, 1971). Group means for the number of correct responses (the maximum score was 40) were calculated. The mean score for the AAT for the students of average reading ability was 23.33 (SD = 7.57) correct. This was four points higher that the mean score for students with reading disabilities which was 18.96 (SD = 8.54). A $\underline{t}$ test was conducted to determine whether or not the difference in phonological awareness between each group was statistically significant. The result failed to reach significance, $\underline{t}$ (1,46) = 1.88, $\underline{p}$ = .067.

The results of the ANCOVA, which are found in Table 4.3, show that the main effect for group was retained, $\underline{F}$ (1,45)= 17.53, $\underline{p}$ < .001. The mean errors per test item, for the group with average reading ability (Group 1), was 1.97 (SD = 0.14). The mean errors per test item for the group with reading disabilities (Group 2), was lower at 1.29 (SD = 0.14). This result indicates that despite any differences in phonological awareness skills, the group with reading disabilities performed significantly better than the group of average readers in the Test of Short-term Memory for Nonsense Strings.

Table 4.3.

Results of the Analysis of Covariance

EFFECT	ANCOVA RESULT
Main Effects	
Group	F (1, 45) = 17.53, p < .001
Vowel Location	F (2, 90) = 1.96, p = .146
Space Location	F (2, 90) = 0.343, p = .710
Two-way interactions	
Group x Vowel Location	F (2, 90) = 2.02, p = .139
Group x Space Location	F (2, 90) = 0.26, p = .770
Vowel Location x Space Location	F (4, 180) = 1.46, p = .217
Three-way interaction	
Group x Vowel Location x Space Location	F (4, 180) = .545, p = .703

The ANCOVA indicates that no significant differences existed for vowel or space location after phonological awareness had been partialed out. Therefore it can be concluded that any differences found in the ANOVA, due to vowel location and space location can be attributed to the phonological awareness skills of the participants. Presumably, the CVC strings were easier than the VCC or the CCV strings because they were phonologically simpler. When phonological awareness was partialled out, the advantage for CVC over the CCV and VCC patterns was lost. Similarly, the - - - XX space location was easier to recall than the X - - - X before phonological awareness had been partialled out, but not after.

The ANCOVA indicated that there were no significant two-way or three-way interactions. Figure 4.2 shows the similarity between the adjusted means for vowel location and group, and the unadjusted means found in Figure 4.1.

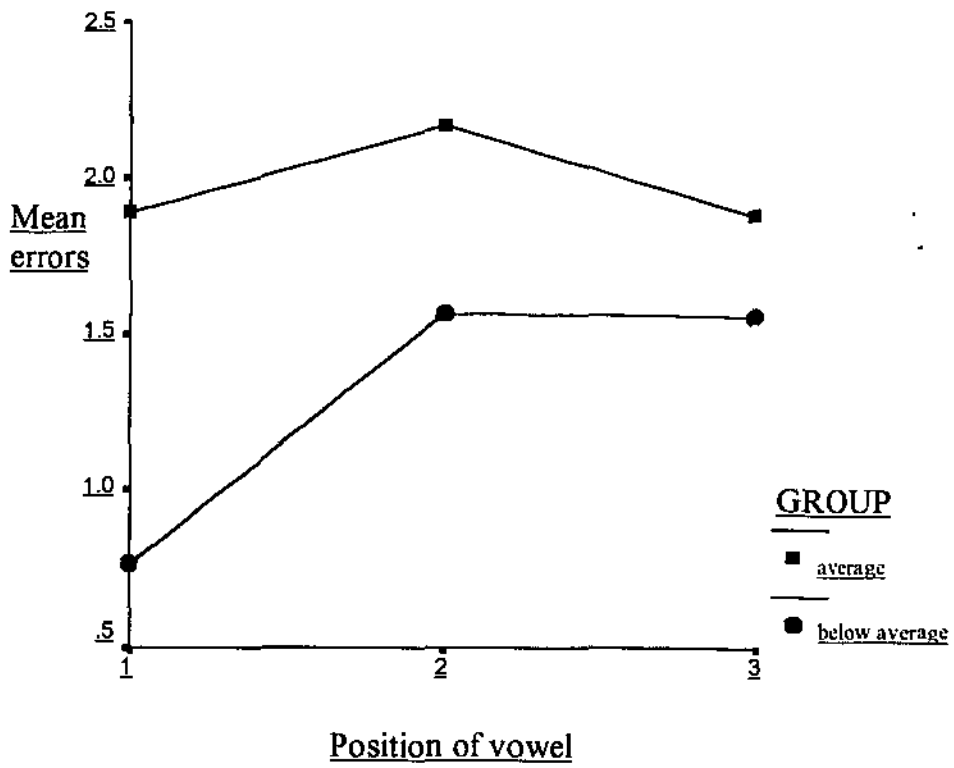


Figure 4.2. The mean errors of each subject group for each of the vowel locations (1-CVC, 2-VCC, 3-CCV) in the ANCOVA.

4.3. Strategies Used by Participants.

Each participant was given the following information prior to commencing the Test of Short-term Memory for Nonsense Strings, "When you have finished the puzzle, I will ask you to tell me what you did inside your head to help you remember where the blocks were." The verbal response of each participant was recorded in writing, and the types of responses given were found to be consistent with three different recall methods:

a) a visual strategy which seems to correspond closely to Baddeley's visuo-spatial sketchpad;

b) a rehearsal strategy which corresponds to Baddeley's phonological loop; and

c) problem solving strategies (including metacognitive strategies).

Examples of typical descriptions of each recall method are shown in Table 4.4. Of particular interest was the final example. This student used a complicated strategy of finger prompts to represent each block location. Two fingers on one hand were reminders of the consonant block locations and two fingers on the other hand represented space locations. The student put the vowel blend into the space remaining after the consonant and space blocks were in place. It is interesting to note that this student had a reading disability. His chronological age was ten years and 6 months and his reading age was eight years and five months (two years below the chronological age). In light of the complex, metacognitive strategy he invented to complete the test, it is not surprising that he made only 4/45 errors on the SMNS.

Table 4.4.

Examples of student responses to the question regarding recall methods used.

Recall Strategies	**Group**	**Response**
Visual	1	I kept looking at it in my head.
	1	I just looked at them really closely.
	1	I looked at them. Then I remembered them.
	2	I pictured them in my mind.
Rehearsal	1	I kept saying them in my head
	2	I said them over and over to myself.
	1	In my head I sounded out the words.
	2	I looked at them and said them in my head..
Problem Solving	2	I saw the /b/ and /d/ and the things in the middle. The /b/ was first and the /d/ at the end. I put the things [vowel blend] in the middle.
	2	Some had a word. I remembered the word and then remembered the blocks. The pattern.
	1	I'd remember the first letter and saw two spaces without the letter first. It would go on and I'd remember that. The pattern comes out.
	2	I looked where the letters were. I used 2 fingers on one hand to remember where the blank spots were and on the other hand I used 2 fingers to remember the /b/ and /d/ and the vowels went in the space.

Not all the strategies used by the children were effective. Several participants described elaborate recall methods but made many response errors. Student 42 described using visual, rehearsal and metacognitive strategies. She said, "I pictured them and said them in my mind. It didn't matter where the blanks were because they were always in the front or the back". Unfortunately this strategy was not particularly effective. This student made 17 errors. Her error pattern showed that she was so confident of the strategy that she was using that she paid little attention to the construction of each nonsense string. Her response to each test item was a CVC nonsense string. This student also failed to realize that /d/ always came before /b/ in her nonsense strings.

Many of the older children with reading problems invented successful strategies. Several children from both groups did not choose to describe their mental processes, and some descriptions were not clear enough to determine the exact nature of the recall method used. For example one student responded, "I concentrated", while another said, "I just remembered".

As there was a significant main effect for group, it was decided to use a chi square to determine whether or not the two groups used significantly different strategies. Each verbal description was examined carefully to determine the recall method used and the results are presented in Table 4.5.

Table 4.5.

The recall methods used by members of group 1 and group 2 .

Strategy	Group 1	Group 2
Visual	10	3
Rehearsal	6	3
Problem Solving	3	8
No Response	5	10
TOTAL	24	24

A chi square was conducted for group and recall method (visual, rehearsal, strategy, or no response) that showed that the difference in strategies used by members of each group was statistically significant. Participants of the younger group of readers, with average ability, were found to be significantly more likely to use visual and rehearsal methods than the older children with reading disabilities. The older children with reading disabilities were found to use significantly more problem-solving strategies than the younger children did, or to have recorded no measurable strategy use χ^2(3, N = 48) = 8.71, p =. 03.

4.4. Letter by Total Errors

Young children experience problems with grapheme similarities (as discussed in the literature review) and it was decided to include two visually similar letters in the nonsense strings to determine whether this problem would persist for older children with reading disabilities. The letters /b/ and /d/ were included in each of the nonsense strings, with 50% of the participants receiving /b/ before /d/ in the nonsense strings and 50% receiving the reverse. A total of ten errors were found due to problems associated with letter orthography (seven inversions of /d/ to /p/, three inversions of /ou/ to /no/, and an inversion of /ei/). The younger student group made all of these errors.

No problems relating to letter orthography were identified in the older group, however two older students mentioned experiencing difficulties with /b/ and /d/ in their strategy descriptions. Student 27 said, "I looked at the two /d/'s and which way they go round and then remembered the rest." This statement indicated either a perception problem or a difficulty recalling the letter being presented. Student 30 mentioned confusion relating to /b/ and /d/ when he said, "I got /b/ and /d/ mixed up". The cause of the confusion may simply have been in remembering which letter came first or it may have been a visual perception difficulty. The average number of errors relating to /b/ and /d/ reversals was calculated, with the result that Group 1 made an average of 1.67 (standard deviation = 1.40), and Group 2 made an average of 1.88 errors (standard deviation = 1.75). A t test determined that this difference was not significant $t(46) = 0.45$, $p = .65$.

CHAPTER 5

DISCUSSION

The chapter begins with a review of the aim of the study and a summary of the findings. The results are then discussed in relation to the research questions. The limitations of the study are presented, and recommendations for future research are made. Implications for current teaching practice are discussed and finally the conclusion to the study is presented.

5.1. Review of the Aim of the Study

This study examined the working memory of students with reading disabilities for recall of positional location in nonsense strings. The SMNS was designed to measure short-term memory skills, and incorporated vowel location and space location elements. The test scores for students with reading disabilities were statistically compared to those of a group of students of average reading ability who were matched by mean reading age. It was evident that differing levels of phonological awareness among participants may have affected individual or group performances. Therefore phonological ability was introduced as a covariate so that the effects of individual variation in phonological awareness levels could be examined.

The aim was to determine how well students with reading disabilities performed on the task compared to younger students of average reading ability who were at the same reading level. A secondary aim was to investigate the strategies used by members of each group to help them remember the nonsense strings. It was anticipated that the students with reading disabilities would perform differently to readers of average ability on the SMNS and that they would also use different strategies.

5.2. Discussion of the Research Questions

5.2.1. Difference Between the Groups

The first research question asked: Will there be a significant difference in the recall of nonsense strings between students with reading disabilities and students of average reading ability? Both the ANOVA and ANCOVA yielded a significant main effect for group. There was a significant difference in the recall of nonsense strings between students with reading disabilities and students of average reading ability. The group of older children with reading disabilities performed significantly better than the younger children of average reading ability, and this was somewhat surprising. Previous reading level match design studies have shown that younger children of average reading ability, perform significantly better than older children with reading disabilities, on phonological awareness tasks (McBride-Chang, 1995; McDougall et al., 1994; Felton & Wood, 1992; Siegel & Ryan, 1988). Because the SMNS incorporates elements of phonological awareness, it was expected that this study would also follow this trend.

The SMNS however, was not a pure test phonological ability. Tests of phonological awareness are presented orally, and responses are also made orally, and immediately after each question. The SMNS was presented visually and responses were made by physically moving the blocks into the correct position, up to seven seconds after the presentation of each item. Participants in the SMNS were using strategies to encode the visual material, transfer visual images to phonological material in working memory, and physically reproduce the string after a time delay. The test of Short-term Memory for Nonsense Strings test provided an opportunity to activate all the systems of working memory: the visuospatial sketchpad, the phonological loop, and the central executive depending on the skills level of each participant.

The performance of the group of children with reading disabilities does not appear to be due to phonological ability. In fact, the phonological awareness of the older group was slightly (though not significantly) lower than that of the younger children. Furthermore, after phonological awareness skill was partialed out in the ANCOVA, the significant main effect for group, in favour of the older children with reading disabilities, was retained. The nature of the SMNS apparently allowed the older children to tap metacognitive processing skills, as well as phonological elements of working memory.

There are several phenomena that could explain this result. The older children may have accessed the rehearsal component of the phonological loop more quickly than the younger group, due to the faster articulation rates that can be achieved by older children (McDougall et. al, 1994). Thus they may have been able to rehearse the nonsense strings more quickly and retain the nonsense string longer than the younger children.

A second explanation, relating to rehearsal in the phonological loop, is that all of the younger children were around eight years old. This is the age, according to Hansen & Bowey (1994), that children first begin to use the rehearsal component of the phonological loop. Therefore, it is possible that some of the younger children had not yet developed this skill. This seems a plausible explanation of why 10/24 of the younger group reported using visual memory techniques (Hansen and Bowey, 1994).

A third explanation of the group differences relates to IQ. The Peabody Picture Vocabulary Test, that was used to measure IQ in this study, only measured verbal IQ. However IQ also consists of a performance component. Poor readers have been shown to be better at performance IQ than verbal IQ (Belmont & Birch, 1966), therefore it is possible that the superior scores of the poor readers may have been due to superior performance IQ. Thus, despite the fact that only three of the older group reported using a visual strategy, it is possible that they may have used superior iconic memory and pictured the blocks in their minds before replicating that picture.

It is possible that the strategies, which many of the older children described, were also related to their performance IQ. The older children may have approached the SMNS as a problem to be solved, rather than a reading activity. They may have been using problem-solving methods taught in remedial and regular class instruction. These children had an average of 2 years more school experience than the members of the younger group, and their intelligence was within the normal range. It can be reasonably assumed that the older children were familiar with problem solving activities, and they were likely to be capable of selecting a strategy to help them complete the SMNS. They may also have been tapping in to phonics instruction received throughout their schooling. The chi square that was conducted to determine the difference in the methods used by each group to complete the SMNS, showed that the older group did in fact, use more strategies than the younger group.

In summary, it is evident that the older group of students with reading disabilities performed better than the younger group of students of average reading ability in the recall of nonsense strings, both in the ANOVA and the ANCOVA. The reason for this unexpected result may have been that they had better rehearsal potential within the phonological loop, or because they had better performance IQ's than the average readers and used strategies to assist in the recall of the nonsense strings. The differences in strategies used by members of each group will be discussed in section 5.2.5.

5.2.2. Vowel Location.

The second research question asked: Will there be a significant difference in recall of nonsense strings that differ in the location of vowels? The results of the ANOVA indicated that there was a significant main effect in the recall of nonsense strings that differ in the location of vowels. There were no interactions between vowel location and any other factor in the ANOVA. There was no significant difference between the older children with reading disabilities and the younger children of average reading ability for vowel location.

The CVC nonsense strings were found to be significantly easier than either the CCV or the VCC nonsense strings for total errors. This is probably because the CVC nonsense strings sound like words and they are easier to read than the CCV, or VCC strings (Treiman, 1992). The CVC strings were constructed with familiar onset and rime configuration to produce the nonsense strings "doub", "deib", "doib", "boud", "beid" and "boid", which can all be pronounced. The onsets were single phonemes (/b/ or /d/) while the rimes consisted of a vowel blend and final consonant ("oid", "eid", "oud", "oib", "eib" and "oub"). This letter configuration has been found to been easier to pronounce than CCV configurations (McBride-Chang 1995). The CCV and VCC were less word-like and they were not constructed in familiar onset and rime patterns. Furthermore, they could not be pronounced very easily e.g. "bdoi" or "eidb". The VCC nonsense strings looked like rimes, except that the final consonants were not familiar consonant blends e.g. /ch/ or /ng/ and they could not be read as a single syllables e.g. "oudb" and "oibd".

It may be assumed that the relatively low number of errors on CVC strings in the ANOVA was related to the phonological ability of the participants. The phonologically aware students, who participated in the study, were able to take advantage of the phonological similarity effect. Good readers are much better at remembering a phonologically non-rhyming (and therefore phonologically rehearsable) string (e.g. /m/, /o/, /e/, /k/, /t/ and /z/) than a rhyming string (e.g. /p/, /t/, /c/, /d/ and /e/). In the current study, the phonologically aware students, were better at remembering the CVC string (which is easily rehearsable) than the unpronounceable CCV and VCC strings (which are not).

The CVC pattern lost its advantage in the ANCOVA when phonological ability was partialled out. This seemed to indicate that those students who found the CVC strings to be easiest were using a phonological awareness skill. The lack of significant interactions for group indicated that members of both groups took advantage of the familiar structure of the CVC nonsense strings and that neither group demonstrated any significant advantage over the other in the recall of the visually and phonemically unfamiliar VCC and CCV nonsense strings.

5.2.3. Space Location

The third research question asked: Will there be a significant difference in recall of nonsense strings that differ in space location? The results of the ANOVA indicated that there was a significant main effect in the recall of nonsense strings that differ in the location of spaces. There were no interactions between space location and any other factor in the ANOVA, and there was no significant difference between the older children with reading disabilities and the younger children of average reading ability for space location. When the effect of phonological awareness was partialled out in the ANCOVA the effect for space location was no longer significant.

The results indicated that the lowest mean errors, for all participants, was the - - - XX location (where X indicates the space location), and that there was a significant difference between the recall of - - - XX and X - - - X space locations. This result seems unremarkable, because the - - - XX configuration was the most word-like string, for space location. Participants viewing - - -XX strings looked at the nonsense string first, and then the two blank space blocks. They may have found this configuration easier to recall as they were able concentrate on the first three blocks, and then place the two blank blocks in place after the nonsense string had been constructed.

Participants may have been slightly confused by the X - - - X and XX - - - strings, as the initial space blocks may have been considered to represent missing letters and not word boundaries. Another problem for the X - - - X string may have been that it required the recall of three chunks of information (a space, the nonsense string, and another space) compared to - - - XX and the XX - - - strings, which consisted of only two chunks (the nonsense string and the spaces). In terms of the constrained capacity comprehension model (Just & Carpenter, 1992), the extra production rules activated due to the processing and storage requirements of the third information chunk, may have resulted in diminished ability to retain the string in memory.

5.2.4. The Effect of Phonological Ability

The fourth research question asked was: Can any of these differences be accounted for by the children's phonological ability? The SMNS involved phonological elements in the nonsense strings. Graphemes needed to be encoded, and letter-sequences needed to be remembered and reproduced. It was expected that the group of students with reading disabilities would have lower phonological ability than the average readers did, and that there would be a significant difference between the two groups in their performance on the SMNS in favour of the younger students

It was surprising that the younger students did not do better than the older students on the test of phonological awareness. The older readers performed better, but the effect was non-significant. To determine the effect of phonological ability on the results it was decided to conduct an ANCOVA using the scores of the Auditory Analysis Test, as the covariate. The results showed that vowel location and space location (which had both been significant in the ANOVA) were no longer significant. These differences in significance can be accounted for by phonological ability. As discussed in the previous sections, it appears that phonological knowledge has assisted students from both groups to recall particular nonsense strings more easily than others (i.e. the CVC strings and the - - -XX strings), but neither group had an advantage over the other with relation to phonological ability.

The significant main effect for group in the ANOVA continued to be evident in the ANCOVA. This indicated that the overall difference between the two groups was not due to phonological awareness. This adds weight to the suggestion that the children with reading disabilities did better than the children of average reading ability, because they were using compensatory strategies to recall the nonsense strings (the next section). There were no significant interactions for any of the factors in the ANOVA and this result remained constant in the ANCOVA.

5.2.5. Differences in Strategies Used.

The final research question asked: What differences in strategy use exist between students with reading disabilities and students of average reading ability? This research question links to the secondary aim of the study, which was to investigate the strategies used by members of each group when solving the Test of Short-term Memory for Nonsense Strings. The different recall methods used by participants were categorized and counted, and a chi square was conducted to determine whether or not there was a significant difference in recall methods between the two groups. Results showed that each group used different recall methods. The older children with reading disabilities approached the SMNS using problem-solving strategies, more than the younger children. The younger children used visual and rehearsal recall methods more than the older children.

Many of the strategies used by the older children involved remembering a pattern in the nonsense strings. The discovery of these patterns reduced the load on working memory through the establishment of production rules that propagated the recurring features of the strings. Participants did not have to rehearse or memorize all the elements of each new string as it was presented

Other older children reported inventing a strategy to make it easier for them to recall the strings. The best example of this type of strategy involved using fingers from each hand to represent different block locations. This strategy reduced the need to rehearse as the student held up fingers for each block location and decreased the number of production rules that needed to be activated.

In summary, it appears the older children with reading disabilities may have performed better than the younger children of average reading ability, because they had more experience at solving problems.

5.3. Limitations of the Study and Recommendations for Further Research

The current study had unexpected results. Firstly, the children with reading disabilities performed better than the average readers, in the task designed for the study. Secondly, the phonological ability of the students with reading disabilities was not significantly different to that of the younger students.

It could be argued that these results were due to poor selection criteria for inclusion into the study. The group with reading disabilities should have included only children of average intelligence with a reading age of two years or more below their chronological age. Unfortunately however, due to time constraints and a limited number of possible participants, some children were included whose reading age was 18 months less than their chronological age. Had the reading age criteria been strictly adhered to, there might have been a significant effect for phonological awareness. It is recommended therefore, that further studies include only students with reading disabilities whose chronological age is at least 2 years greater than their reading age. A second problem with the selection criteria related the test of general ability that was given to each participant. The PPVT was a test of general verbal ability, and children with lower than average verbal ability were excluded from the study. It has been noted that it was difficult find a group of young children, whose mean chronological age and reading age was 8 years and 3 months. Most of the year 2 children that were able to be included in the study had a comparatively high reading age. In fact the final group of average readers had a mean reading age of 8 years and 10 months. This difficulty may have arisen because the PPVT eliminated less able younger readers. The inclusion of a test of performance IQ may have eliminated this problem.

Care was taken to exclude any children with reading disabilities, who were participating in reading clinics. Some students may however, have been receiving remedial education within their school environments, and thus they may have been provided with specific training to assist in overcoming word reading difficulties. This may have affected their performance in the SMNS. Furthermore, the phonological awareness of some of the students with reading disabilities may have been augmented by the use of compensatory strategies or by specific training.

The recall methods used by each participant proved to be particularly relevant to the overall result. It is suggested that responses of each participant should have been recorded rather than written, to provide a richer and more accurate source of data.

Another limitation of the study is the complexity of the task. The SMNS involves letter recognition, memory and manual dexterity in arranging the blocks quickly. The test could be performed in various ways (i.e. visualization, rehearsal and problem solving) therefore it was difficult to determine just what was being measured. Further research might involve giving the SMNS, as well as other memory and phonological awareness tasks to a group of children to determine the extent to which these skills contribute to performance on the SMNS.

5.4. Implications for Practice

It is evident from the results of this research that older children with reading disabilities use different strategies to younger average readers, when reading unfamiliar words. The nature of those differences appears to be linked to the successful use of problem solving strategies and metacognitive techniques to perform the memory tasks involved with reading new words. Despite the use of these strategies however, the older children with reading disabilities do not seem to develop the reading skills necessary to enable them to read at an age appropriate level. Children with reading disabilities who use strategies to assist in reading tasks, may be difficult to identify in a class, especially as they get older. They may become proficient at using compensatory strategies to enable them to perform better than would be expected (from their reading level) on reading related tasks such as in this study.

5.5. Conclusion

The findings of this study were that children with reading disabilities performed significantly better than children of average ability, in a memory task involving nonsense strings. The study indicated that children with reading disabilities were able to compensate for reading deficits by using strategies that enhanced their performance. It was also found that phonological ability of the participants did not affect their performance on the task designed for this study.

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APPENDIX A

AUDITORY ANALYSIS TEST

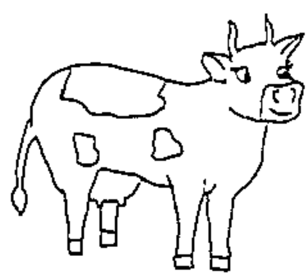
A. cow(boy)

B. tooth(brush)

1.	birth(day)	21.	(sh)rug
2.	(car)pet	22.	g(l)ow
3.	bel(t)	23.	cr(e)ate
4.	(m)an	24.	(st)rain
5.	(b)lock	25.	s(m)ell
6.	to(ne)	26.	Es(ki)mo
7.	(s)our	27.	de(s)k
8.	(p)ray	28.	Ger(ma)ny
9.	stea(k)	29.	st(r)eam
10.	(l)end	30.	auto(mo)bile
11.	(s)mile	31.	re(pro)duce
12.	plea(se)	32.	s(m)ack
13.	(g)ate	33.	phi(lo)sophy
14.	ti(me)	34.	s(k)in
15.	(c)lip	35.	lo(ca)tion
16.	(sc)old	36.	cont(in)ent
17.	(b)reak	37.	s(w)ing
18.	ro(de)	38.	car(pen)ter
19.	(w)ill	39.	c(l)utter
20.	(t)rail	40.	off(er)ing

APPENDIX B

PICTURE CUES FOR AUDITORY ANALYSIS TEST





APPENDIX C

THE SIX ORDERS OF PRESENTATION FOR THE TEST OF SHORT-TERM MEMORY FOR NONSENSE STRINGS

Number 1 'd' before 'b', vowel blend pattern 1.

		d	b	ou
	ei	d	b	
oi	d	b		
	d	ou	b	
		ei	d	b
d	b	oi		
d	ou	b		
		d	ei	b
	d	b	oi	

Number 2: 'd' before 'b', vowel blend pattern 2.

		d	b	ou
	oi	d	b	
ei	d	b		
	d	ou	b	
		oi	d	b
d	b	ei		
d	ou	b		
		d	oi	b
	d	b	ei	

Number 3: 'd' before 'b', vowel blend pattern 3.

		d	b	oi
	ou	d	b	
ei	d	b		
	d	oi	b	
		ou	d	b
ei	d	b		
d	oi	b		
		d	ou	b
	d	b	ei	

Number 4 : 'b' before 'd', Vowel blend pattern 1

		b	d	ou
	ei	b	d	
oi	b	d		
	b	ou	d	
		ei	b	d
b	d	oi		
b	ou	d		
		b	ei	d
	b	d	oi	

Number 5: 'b' before 'd', vowel blend pattern 2.

		b	d	ou
	oi	b	d	
	ei	b	d	
	b	ou	d	
		oi	b	d
b	d	ei		
b	ou	d		
		b	oi	d
	b	d	ei	

Number 6: 'b' before 'd', vowel blend pattern 3.

		b	d	oi
	ou	b	d	
ei	b	d		
	b	oi	d	
		ou	b	d
b	d	ei		
d	oi	d		
		b	ou	d
	b	d	ei	

APPENDIX D

PROFORMA: AUDITORY ANALYSIS TEST

Test 1

Student Number______________ Age ______________

School ______________ Date ______________

1		21	
2		22	
3		23	
4		24	
5		25	
6		26	
7		27	
8		28	
9		29	
10		30	
11		31	
12		32	
13		33	
14		34	
15		35	
16		36	
17		37	
18		38	
19		39	
20		40	

APPENDIX E

PROFORMA: REVISED NEALE ANALYSIS OF READING ABILITY

Test 2

Student Number ____________________ Age ____________________

School ____________________ Date ____________________

Raw Score Reading Accuracy ____________________

Standardized Score (reading age) ____________________

APPENDIX F

PROFORMA: PEABODY PICTURE VOCABULARY TEST - REVISED

Test 3

Student Number______________ Age ________________

School ____________________ Date ________________

41		61		81		101	
42		62		82		102	
43		63		83		103	
44		64		84		104	
45		65		85		105	
46		66		86		106	
47		67		87		107	
48		68		88		108	
49		69		89		109	
50		70		90		110	
51		71		91		111	
52		72		92		112	
53		73		93		113	
54		74		94		114	
55		75		95		115	
56		76		96		116	
57		77		97		117	
58		78		98		118	
59		79		99		119	
60		80		100		120	

Raw Score ________________

Standardized Score ________________

APPENDIX G

PROFORMA: TEST OF SHORT-TERM MEMORY FOR NONSENSE STRINGS

for 'b' before 'd', vowel blend 2

Test 4

Student Number______________Age __________________

School ______________________Date __________________

B/D _____________________Start # _________________

Vowel Blend Pattern __________

xxbdou					
xoibdx					
eibdxx					
xboudx					
xxoibd					
bdeixx					
boudxx					
xxboid					
xbdeix					

Recall Strategies

APPENDIX H

PARENT CONSENT LETTER:

Linda Lane
Ph: 446 6908

Dear Parent or Legal Guardian,

I am an Honours student at Edith Cowan University conducting research into how children learn to read. I would be pleased if you would allow your child to participate in my study, which consists of a series of short, simple puzzles, that all children enjoy. The puzzles will take about 30 minutes to complete.

The data gathered in this study will be used to examine how children remember the words that they read. All records will remain strictly confidential and participants are free to withdraw at any time. The completed thesis will be made available to the principal of your child's school.

Any questions concerning this research, entitled Short-term Memory for Nonsense Strings in Children with Reading Disabilities, can be directed to Professor Peter Cole at Edith Cowan University on 273 8405. Please complete the attached permission slip and return it to your child's teacher.

Yours faithfully,

Linda Lane (Diploma of Teaching)
4.4.97

Student's Name ________________________________

School ________________________________

I ____________________________ (parent or guardian's name), have read the information on the above page and any questions I have asked have been answered to my satisfaction. I agree to my child ______________________(child's name) participating in the study, with the understanding that he/she may withdraw at any time. I agree that data gathered may be published, provided my child is not identifiable.

Signature of Parent or Guardian   Date

APPENDIX I

PRINCIPAL CONSENT LETTER

The Principal

Dear ________

I am currently completing an Honours degree in Education entitled "Short-term Memory for Nonsense Words in Children with Reading Disabilities". I have spent many hours gathering data, which I hope, will shed light on the reading process. I have identified my experimental as group having a mean reading age of eight years and three months and commenced data collection from the control group whose mean chronological age will be eight years and three months.

I would very much appreciate it if you would give permission for me to use children in the school as part of the control group. I need to test about 15 grade three students and will spend about 30 minutes with each child conducting a series of simple puzzles. All the children find these puzzles easy and enjoyable. The anonimity of the participants and confidentiality of all records is assured. A copy of the completed paper will be forwarded to the school. Any questions concerning the study can be directed to Professor Peter Cole of Edith Cowan University on 9273 8512.

Yours faithfully

Linda Lane (Diploma of Teaching)

I ___________________ (name of Principal) have read the above information and any questions I have asked have been answered to my satisfaction. I agree to students from ______________________ (name of school) participating in the study, with the understanding that they may be withdrawn at any time. I agree that the data gathered for this study may be published, provided my students and school are not identifiable.

Principal's signature ________________________________ Date __________

Investigator's signature ______________________________ Date __________